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Dr. BOERHAAVE'S
Academical Lectures

ON THE
Theory of PHYSIC.

BEING

A Genuine Translation of his

INSTITUTES

AND

Explanatory COMMENT,

Collated and adjusted to each other, as they
were dictated to his STUDENTS at the
University of *Leyden*.

V O L. II.

Containing the Structure and Action of the
vital or *sanguificative* Organs; *viz.* the
Heart, Lungs, Blood and its Vessels, Glands,
Brain and Nerves, &c.

L O N D O N :

Printed for W. INNYS, in *Pater-Noster Row*.

M D C C X L I I I .

19138



W. V. A. M. S. E. 1890
1890

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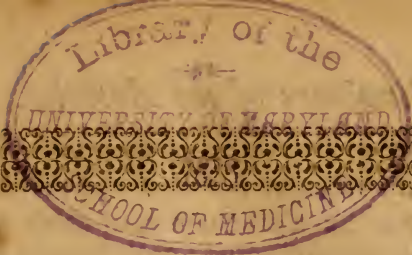


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The Structure of the Arteries and Veins.

§. 131. **T**HE red Liquor, called Blood, is found distributed thro' almost all Parts of the Body, and appears in its natural State to be contained in proper Vessels, or Tubes, term'd Arteries and Veins; or else in some intermediate Receptacles between those Vessels, such as the venous Sinus's of the Heart, Liver, and dura Mater, with the Auricles and Ventricles of the Heart, and the spongy Substance or Cells contained in the Parts of Generation of the Male and Female, and perhaps in the Spleen.

§. 132. The *Arteries*¹ appear to be membranous Canals of a *conical*² Figure, variously *ramified*³ and inflected in oblique Directions; being smooth on their Inside, and without any *Valves*⁴, except at the Heart; their smaller Branches arise from the larger Trunks *variously*⁵, but generally in acute Angles towards their Extremities, seldom at right Angles, as in the Intercostals; and more seldom in obtuse ones, as in the umbilical Arteries of the Fœtus, &c. They consist of five Coats⁶, as described by Anatomists; the most *external*⁷ of which is thin and *nervous*⁸ in its exterior Surface,

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2 *Structure of the Arteries.* § 132.

face, but internally it is composed of a very thick and vascular *Network* ⁹ of Arteries coming from the Coronary and other Branches, and interwoven with small Veins, by which vascular Plexus the arterial Trunks are connected in their Situations. The second is a thin and *cellular* ¹⁰ Coat, but very dilatable by inflating its Cells, wherein is naturally contain'd an oily Fat, which being pressed out upon the muscular Fibres of the next Coat, lubricates them, and renders them well adapted to perform their constant Dilatations and Contractions. The third, or *glandular* ¹¹ Coat, is probably no more than Part of the former, consisting principally of the adipose Ducts and Cells, which immediately invest the fourth or muscular Coat which is made up of annular Fibres, very strong, *elastic* ¹², and closely compacted together in several *Strata* ^{12*} one within the other, into which they are divisible. The fifth and last Coat, which lines the internal Surface of the Artery, is thin and membranous, composed of longitudinal Fibres, capable of Contraction and Dilatation like the former. This whole Vessel, while the Animal is alive and well, moves and beats with a vibratory Motion; but its *smaller Branches* ¹³ are variously disposed and formed, so that the Structure of this Vessel is very different in various Parts of the Body, both in the Size of its *Orifice* ¹⁴ arising from the larger Trunk, the Thickness of its Coats, Number of its Branches, and their different Inflections,

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§ 132. *Structure of the Arteries.* 3

Intertexture and *Distribution* ¹⁴ *, &c. The Extremities of these Arteries terminate either into the Beginnings of the small *Veins* ¹⁵, forming a continued *Tube* ¹⁶ with them, without any cavernous Medium ; or else they are distributed to, and end in various Ducts, Cells, and large or small Cavities in several Parts of the Body, where they discharge or exhale a thin Liquor to mollify the Surface of the Membranes, and prevent them from growing together ; while others of them end in *excretory Ducts* ¹⁷, or in particular *Sinus's* ¹⁸, as those of the Penis, Clitoris, and Spleen, or lastly, they are distributed *directly into secretory Canals* ¹⁹, or else into a glandular *Pulp* ²⁰.

¹ The Name *Artery* is derived, (ἀπὸ τῆς τὸν ἀέρα τηρεῖν) from its containing Air ; for the first Vessel thus denominated, was that we now call the *Trachea* or Windpipe, the Arteries themselves being in the early Times of *Hippocrates* termed *beating* or *internal Veins*, in Contradistinction to the external Veins, which have no Motion. But after *Hippocrates*, the Notion of *Erasistratus* prevailing, till it was refuted by *Galen*, that the Canals we now call Arteries, received a Quantity of Air in their Diastole from the Heart, which they expelled in their Systole ; these Vessels were from that Time named *arteriæ*. This Air they supposed the Arteries received, from the left Ventricle of the Heart, which again took it from the Lungs ; holding likewise, that the same Ventricle received but a very little Blood which transfused into it, thro' the muscular Septum of the Heart. At that Time they distinguished two Kinds of Air-vessels or

4 *Structure of the Arteries.* § 132.

Arteries, arising from the left Side of the Heart; the one which we call the *Aorta*; they by way of Eminence named *arteria arteriosa*; the other, which appear to have the Structure of a Vein, they termed *arteria venosa*. The Veins were then defined to be those Vessels which came out of, and convey'd the Blood from the right Ventricle of the Heart: These they distinguished into the (φλεψ κοίλη *vel* μεγάλη, or) *vena cava*, and the (φλεψ αρτηριώδης, or) *vena arteriosa*, which last is what we now call the pulmonary Artery. This was the Doctrine received and taught in the physical Books and Schools, till the Time of *Harvey*, by whose Discovery, we are now enabled to remove the Error and define an Artery that Vessel which conveys Blood from the Heart to the other Parts of the Body, and a Vein the reductory Canal which returns the Blood sent by the former from all Parts of the Body, again to the Heart.

2 A Cone among the Mathematicians is defined a Pyramid, every transverse Section of which is circular; and in this Sense the Arteries are converging Cones: Since their Bases or Segments next the Heart, are always larger than those towards their Apices or Extremities in which they terminate; and accordingly the transverse Section or Diameter of every Artery, is less as it becomes more remote from the Heart. Yet we are not from hence to conclude, that taking the *Aorta* and its Branches as an Aggregate, its greatest Diameter must be nearest the Heart; for the transverse Sections or Diameters of all the smaller Arteries added together, will infinitely exceed the Diameter of the *Aorta* at the Heart: However, the Arteries may be reasonably termed conical, or converging Cones as to Sense: (1.) Because they have the real Qualities or Affections of such a Cone,

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Cone, *i. e.* the Trunk or Basis next the Heart being distended, all its smaller Branches will be also dilated at the same Time; whereas if they had the Affections of a Crescent, or inverted Cone, it must follow, that the Branches would not be dilated, tho' the Trunk or Basis next the Heart be distended; nor does the Impulse of the Blood appear sufficient to dilate the Arteries, were they every where of an equal Diameter. (2.) Because the Aorta and every Artery taken without its smaller Branches, appear in all Respects to be really a converging Cone. Lastly, We wou'd rather have the Arteries termed *conoide* than conical, or real Cones; because all of them are more or less inflected, so as to describe some kind of Arch or Angle: But this they cannot do, without changing the Axis of the Cone, from being perpendicular to its Basis; and therefore they cannot be strictly termed Cones.

³ All the Arteries, traced down to the very minutest, appear to be thus more or less ramified; though some of them run entire, a considerable Length before they divide, as we commonly observe in the Carotids, from the Aorta to their thyroide Branches.

⁴ There is no Artery in the Body, in which the Blood has not a free and ready Passage into any of the rest; and the Artery itself will even become a Vein, and return the Blood back again to the Heart, if the impelling Force be greatest at its Extremity; upon which Principle, I have seen the Body of a male Infant, injected by a small Artery in the Groin, so as to fill the whole arterial System very exactly.

⁵ This Variation of their Rise is manifold, differing, (1.) According as their Trunks are nearer to, or more remote from the Heart. 2. As

6 *Structure of the Arteries.* § 132.

some arise from the anterior Part of the Aorta, like the Spermaties ; others from its Sides, in opposite Directions, as the Intercostals, and Coronaries ; and others again arise more laterally, as the inferior mesenteric Artery, &c. 3. According to the Angle which the arterial Branch makes with the Trunk from whence it proceeds : Thus some Arteries with their Trunks intercept a very acute Angle, as the Spermaties ; others intercept an Angle of about 45 Degrees, which is the most frequent among them ; and others again strike off in right Angles, as the Emulgents. And lastly, Some Branches with their Trunks, make an obtuse Angle, as the coronary Arteries of the Heart with the spinal Arteries which arise from the vertebral, and descend through the middle of the spinal Marrow ; for the vertebral themselves are only distributed on the outside thereof. These are the principal Differences of their Origination, and which merit our Notice, because those Parts of the Blood which are the most solid and move with the greatest Velocity, always endeavour most to continue in the same Course in which they were at first moved ; while the lighter Particles of that Fluid which have the least Density, pass off at more right Angles.

6 The larger Trunks only, have all these five Coats, before they are distributed into any Part ; for when an Artery enters into any Viscus it puts off the exterior Tunic ; and when the Arteries enter into the Bones, they even put off their muscular Tunic as well as their exterior one, so that within the Cavities of the Bones they become almost thinner than the Veins.

7 This external Tunic is derived to the Aorta, partly from the very thin Membrane which closely invests the muscular Fibres of the Heart externally,
and

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and in Part from the Pericardium and Pleura ; but after the Trunk of the Aorta has passed thro' the Diaphragm, it in like manner receives its external Tunic from the Peritonæum, and the other common Membranes of the several Cavities thro' which it passes.

⁸ It is termed nervous, not from its being either extremely sensible, or plentifully supplied with small Nerves ; but because it appears white, its Blood-vessels escaping the naked Eye, unless they are distended with some Injection.

⁹ This Net-work of small Arteries, which is pretty thick, comes from the Coronaries, and invests the whole Superficies of the Aorta near the Heart, immediately under the nervous Tunic. This appears from the Experiments of *Ruyfch*, whose fluid ceraceous Injection has filled the left Auricle and Ventricle of the Heart, so as to pass into its coronary Arteries, and render all their small Branches, spent on the Coats of the Aorta, very conspicuous. A remarkable Peculiarity of this Plexus is, that it is filled, or in its Diastole, when the Aorta is in its Systole, and emptied when the Aorta is in its Diastole ; and therefore the Contraction and Dilatation of this arterial Plexus must be always made in opposite Times to those of the Aorta, and at the same Times with those of the coronary Arteries. (§. 183.) For when the Aorta is fullest of Blood, at that Instant only does it fill both the coronary Arteries ; and at the same time, when the muscular Coat of the Aorta contracts, the cellular one does not, having no such contractile Power ; so that by this Means there is made a Dilatation or Space betwixt the muscular Coat contracting itself towards the Axis of the Aorta, and the external nervous Tunic, into which Space the Blood rushes by the coronary

8 *Structure of the Arteries.* § 132.

Arteries, so as to fill all their small Branches spent on the Aorta; by which Repletion of the Arteriolæ the Contraction of the Aorta is also further augmented. But when the Aorta, after its utmost Contraction, is again filled by the Systole of the Heart, with more Blood from its left Ventricle, its muscular Tunic will be then distended, so as to compress and empty the small Vessels spread upon it; which therefore cannot at that time receive any Blood in them from the Coronaries, which are also at that instant empty.

¹⁰ This cellular or adipose Membrane, in whose Substance run the small Vessels of the preceding Plexus, being interposed betwixt the nervous and muscular Coat, prevents them from growing to each other, and pours out its lubricating Oil upon the Fibres of the latter, which are perpetually in Motion.

¹¹ They are protuberant Corpuscles, appearing in the cellular Tunic, which seem to afford a lubricating Mucus; or they are perhaps no more than distended Vesiculæ in the same adipose Membrane next to the muscular Tunic.

¹² * One may by Patience and Maceration separate almost an hundred of these Strata or Lamellæ in the Aorta of an Ox; in which this muscular Coat is near two Lines thick.

¹² Such is the Elasticity of the Aorta, that it will receive above an hundred Pints of Water, without bursting; by which Power it is, that the Arteries continue to contract and lessen their Diameters even after the Heart has ceased to move, so as to discharge almost all their contained Blood into the Veins; which therefore appear livid and conspicuous, while the Arteries are in a manner empty and contracted in the dead Subject.

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¹³ It was a great Error in the learned *Bellini* and *Malpighi*, to consider all the Extremities of the Arteries as a Network of Vessels dividing and again terminating into each other in the same Manner; upon which Supposition the former has built a System with more Ingenuity than Truth. 'Tis indeed certain, that in the Heart and Lungs the Arteries barely ramify, and then immediately return again in Veins; but the great *Raysh* seems to have been the first who has demonstrated that the extreme Branches of the Arteries, are differently disposed in almost every different Part of the Body. In the Liver they appear like small Pencil Brushes, in the Testicles they are wound up like a Ball of Thread, in the Kidneys they are inflected into Angles and Arches, in the Intestines they ramify like the Branches of Trees, in the Uvea they form Circles and Radii, in the Brain they are waved in and out in a serpentine Course; in the Omentum they are disposed something like the Marshes of a Net, and in almost every other Part of the Body they assume a different and peculiar Structure.

¹⁴ The Sections of the Arteries as they arise, do not decrease in an inverse Ratio to their Distances from the Heart, as they must if they were framed mechanically by the Impulse of the Blood, according to the Opinion of *Cartesius*. On the contrary, the very first Arteries we meet with, the Coronaries, are but small, when the very next are the large carotid and subclavian Branches; after which come the little Twigs to the Thimus and the Intercostals, then the large Mesenteric, Coeliac and emulgent Branches, and immediately after them the slender spermatic Arteries: From whence it is manifest, that the human Body was not formed by a spontaneous Mechanism, but that

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that its Parts were thus built for the designed and foreseen Uses intended them by the most wise Creator.

¹⁵ When a small Artery is near spent, it sends off many little Branches; at each of which its Membranes are put off, or render'd thinner, till at last, where they become smallest, thinnest, and without Branches, they acquire a cylindrical Figure; and then nothing more is required for its becoming a Vein, but that it be reflected back again.

¹⁶ In this Manner terminate most of the Arteries spent upon the membranous Parts, where there is but little Secretion, according to the Demonstration of *Lewenhoec*.

¹⁷ Of these there are various Kinds, the most numerous are those which exhale the perspirable Matter of *Sanctorius*, being seated wherever the Skin is extended. Those excretory Tubes being dilated by the Humours receiving a greater Impulse from the Motion of the Muscles, &c. do then transmit the brackish and aqueous Part of the Blood, which we call Sweat; and by urging the Circulation more violently, they will discharge the very Serum itself, which will concrete; but they never transmit the Cruor, unless it be in Women, when the hypogastric and spermatic Arteries being distended from a Plethora, discharge the menstruous Blood periodically this Way. There are another Set of excretory Ducts which do not discharge any thing out of the Body, but only exhale a thin Vapour into several Cavities, some of which are very small, and only large enough to receive Parts, or allow them Motion; others of these Cavities are much larger, as the Ventricles of the Brain, the Cavity of the Pericardium, Thorax and Abdomen. That there are such excretory

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cretory Ducts in those Cavities, is apparent from Injections escaping into them that Way; and it is also as apparent, that this Moisture must be again absorbed, otherwise it would be turned into a Water.

¹⁸ The Blood is for a Time found in a manner extravasated in some Parts; as when in the venereal Act it is pour'd out of the patulent Orifices in the Arteries into the spongy Substance in the Parts of Generation of both Sexes, and then again returned by absorbing Orifices of the reductory Veins.

¹⁹ The small Arteries terminate sometimes in cylindric Vessels or Ducts, which have no intermediate Receptacles, but discharge their secreted Liquor immediately into the Cavity for which it is designed. Thus it is in the villous Coat of the Intestines; in the *tubuli Belliniani* of the Kidney, which convey the Urine from the Arteriole strait into the Pelvis and Ureter; and possibly the same Mechanism may obtain in the Uterus. Other small Arteries again, let their secreted Fluid drain into some Receptacle, in which it stagnates, thickens, and meliorates; as the Bile in the Liver, the Semen in the Epididymis, and all glandular Juices in their Folliculi.

²⁰ As is the Case in most of the Viscera; but whether this Pulp is made up barely of small Vessels spun out to a great Fineness, or whether it is composed of Folliculi or Cells, upon which the small Arteries are spent and ramified, is the Subject of another Consideration. See §. 264 and 265. But this is certain, that not any of the Arteries terminate in blind Ducts that have no Passage; for if that were the Case, the Blood's Circulation wou'd be soon brought to a Period. Nor is the Blood extravasated from any of the Arteries,

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ries, so as to stagnate and form the Parenchyma of the Viscera, as the Ancients imagined. It was indeed the Opinion of *Ruysch*, that the Blood transfused thro' the Pores of the Vessels like Dew, in order to nourish the solid Fibres; into which Notion he was led by the following Appearance: Having accurately filled a Heart with a soft Injection like Wax, he cut it open, and dipt it in *Oleum Terebinthinæ lavendulatum* (which leaves a glossy Varnish upon prepared Parts, that preserves them from any Danger of Putrifaction or Decay :) Some Time after, viewing it in the Sunshine, there appeared red Spots within Side of it. These Spots, said *Ruysch*, are the Injection extravasated under the Varnish, without any Rupture or Injury offer'd to the Vessels, just in the same Manner as the Blood transfuses in the living Subject. But for my own Part. after carefully examining that Preparation with the utmost Attention, I am persuaded that those Spots were in reality the Penecilli of the Vasa Exhalantia, each of which were so turgid with the Injection, as to appear together in the Rays of the Sun like one continued Spot.

§. 133. The *Veins* ¹ have almost the same Figure and Distribution with the Arteries, only formed with a *larger Capacity* ², and generally *more in Number* ³; but all of them have their Membranes or Coats much *thinner and weaker* ⁴ than those of the Arteries. *Valves* ⁵ are also frequent in the Veins, which are generally single at the Insertion of the venal Branches into their larger Trunks, being oblong, and almost shaped like the Finger of a Glove;

§ 133. *Structure of the Arteries.* 13

Glove; but in the perpendicular Trunks of the larger Veins, at some Distance from the Heart, they are generally placed two together, to promote the Ascent of the Blood in its perpendicular Course; and such is their Structure and Connection within the Vessels, that they admit the Blood to pass forward from the smaller Branches into the larger Trunks, but prevent its Regress whilst the Heart is contracted, and sustain its Weight. The Veins in the living Animal have *not naturally any Pulsation*⁶, nor any throbbing Motion like that of the Arteries. Their smallest Extremities arise variously, as those of the Arteries were observed to terminate differently; some of their Anastomoses or incipient Roots coming from the *bibulous Pores*⁷ in the Cuticle; others from the *absorbing Ducts in the thin Membranes*⁸, which line all the internal Cavities of the Body, great and small, forming *Cryptæ* and *Folliculi*; and others of the incipient Veins arise immediately from the Extremities of Arteries, or else from analogous Ducts, or Sinus's, like those of the Penis, Clitoris and Spleen; or, lastly, from a glandular Pulp.

¹ Tho' the Veins receive all their Blood from the Arteries, yet they also absorb some thinner Juices from many other Vessels; but I cannot think a Patient can receive any Benefit from a Bath of Blood, recommended by the Ancients. There are indeed some Arteries without their corresponding Veins, as those which convey blood into the Uterus.

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² The Veins are often three or four times as large as their corresponding Arteries, and sometimes larger, as in the Emulgents. So also the Sinus of the Vena Cava vastly exceeds the Dimensions of the Aorta at the Heart. But tho' there is, by this means, more Blood running at once in the Veins than in the Arteries, yet a greater Quantity passes the Arteries in a given Time than the Veins; for the Impulse or Momentum of the Blood in the latter being much weaker, it there moves slower, and occasions an Enlargement of this weaker Vessel; or, which is the same, if equal Quantities of Blood pass into and from the Heart in the same Time by the Vena Cava and Aorta, it must in the first pass three times slower than in the last, because the Diameter of the Vein is thrice that of the Artery. There was a Necessity for the Veins to be made much weaker than the Arteries, that they might not too much resist the Action of the latter, but give way and receive their Blood, as also an additional Quantity of Chyle. But yet the Veins are not so much larger than the Arteries as they commonly appear in Dissections; for after Death the Arteries continue to contract themselves by their greater Strength, assisted with the Cold, and discharge their Blood into the less resisting Veins, by which means the latter appear distended beyond their natural Dimensions in Life, while the Arteries are as much less or more contracted.

³ One Example we have of two Arteries to but one Vein, in the Navel-string of the Fœtus; but even there the one Vein much exceeds the Diameter of the two Arteries. But if we inspect the Mesentery, and most of the Viscera, we shall find them much larger and more numerous than their Arteries. Some Veins there are without a corresponding Artery, as the Vena Azygos, &c. Lastly,
There

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There are an infinite Number of bibulous Veins, which greatly exceed the Size and Number of their corresponding Arteries. Consider how readily Water enters into the Diver so as to make him swell, and abate his Thirst without drinking, with the Experiments at *Note 12.* to §. 87.

4 The Fibres of their Tunics, tho' of the same kind with those of the Arteries, are much weaker, and less elastic. The Veins have their Coats the thinnest where they arise from the Arteries; from whence they become stronger and thicker as the Veins enlarge, till at the Heart they are near as strong as the Coats of an Artery. This holds true as well of the Trunk and Branches of the Porta, as the Cava; for the Branches of the mesenteric Veins are the more robust as they are nearer their Heart, or Sinus of the Trunk of the Porta; which last, where it ramifies in the Liver, is exceeding robust like an Artery, which it then every way resembles.

5 These Valves were formerly observed by *Fabricius ab Aquapendente*, tho' he could not assign their Uses. They are found in the Veins at the Heart, at the Insertion of the Vena Azygos into the Cava, at the Entrance of the thoracic Duct into the Subclavian, at the Liver, at the Opening of the Emulgents, and in the Veins of Limbs. Their Office is to sustain the Blood, and prevent it from returning back in the Veins, while it is not admitted forwards into the Heart, during its Systole; but when the right Ventricle is relaxed, so as to receive the Blood which then comes forward, the Valves open and propel it to the Heart. These Valves are also frequent in the Veins of the upper and lower Limbs, as they are there very necessary; because the Blood would from its Weight, slow Motion, and the Cold, become stagnant if its
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Course was not thus promoted. As for the Valves placed at the Opening of venal Branches into their Trunks, they serve chiefly to prevent the Blood from returning out of the Trunks into the Branches, which wou'd overcharge the latter, when the former are pressed in straining, &c. Which last is also the Use of those Valves found in the Sinus's of the dura Mater, at the Entrance of the Veins from the Pia Mater, which prevent the Blood from returning back out of the former into the latter. Lastly, Those in the jugular Veins, at their joining with the Subclavians, prevent the Regress of the Blood in the same Manner, and for the same Uses.

⁶ But when the Veins are tied or obstructed in any Part, they are somewhat agitated by the Impetus of the Blood, drove on by the Arteries against the Obstacle : and this occasions that throbbing Motion in them, which is sometimes perceptible in Inflammations.

⁷ Absorbing Veins are found distributed in all Parts which have any exhaling Arteries. Among such Veins we may reckon those that absorb the aqueous Humour of the Eyes ; for if that be discharged, it will be again restored in twenty-four Hours ; which argues, that the Separation of this Humour from the Arteries is made very swiftly ; so that it wou'd be accumulated in vast Quantities, if it were not returned by the absorbing Veins with the same Velocity that it is secreted from the Arteries.

⁸ All the Juices in the Body become thicker than they were secreted, barely by stagnating with the Dissipation and Absorption of their more fluid or aqueous Parts ; which have no other way of escaping out of the internal Cavities, but by entering small bibulous Vessels, which return them into the sanguiferous Veins. The Semen, for Example, at
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its first Secretion in the Testicle, is as fluid as the Tears ; but it this way becomes inspissated into a perfect Glue in the seminal Vesicles. Lastly, in the Thorax, Abdomen, and all other Cavities of the Body, which are supplied with a vapoury Dew discharged from the patulent Arteries, (and which upon opening Animals lately kill'd, has a very disagreeable and peculiar Smell) there must of necessity be other absorbing Veins to return or discharge the same.

§. 134. Every one of these Arteries, (§. 132.) which are found dispersed throughout the whole Body, do all of them join and communicate by an open and free Passage, to the Body one way, and to the Aorta the other; the Trunk of which last arises from the left Ventricle of the Heart: But those Arteries which compose the Lungs arise in the same manner from the *Pulmonary Artery*¹, whose Trunk comes from the right Ventricle of the Heart; which we are taught from the Appearance of both those Vessels, when distended with ceratious *Injection*²; but the Ancients traced them without that Artifice, tho' they could not descend to their ultimate Branches for want of it. Lastly, The Orifice of the Aorta and Pulmonary Artery at the Heart are of equal Dimensions.

¹ The Compages of Arteries in the Lungs has undoubtedly the same Mechanism with that of the other Arteries of the Body, as they are divided into the same different Orders or Series: From the sanguiferous Branches of the pulmonary Artery
C arise

arise serous Arteries, as in the other Parts of the Body ; from the serous arise lymphatic Arteries, which again arise from each other in lesser Orders. The Lungs have also their Nerves, and all the Species of Vessels that are found in other Parts.

² This curious Artifice, which was contrived by that industrious Naturalist Dr. *Swammerdam* before 1666, has been since so much cultivated and improved by the celebrated *Ruyfch*, that his Preparations have surprised even the most learned Part of Mankind. We are by this means enabled to view the whole arterial System from the Heart, even to where their smallest Twigs join with the incipient Veins ; hereby we trace them into the exhaling Vessels, into the Villi of the small Intestines, and into the pulpy Substance of the softest Viscera. The larger Branches of the Blood-vessels have indeed been traced with surprising Exactness, by Excarnation only, by the indefatigable Pains of *Eustachius* ; and this he has done to such a Degree of Perfection as may astonish our Moderns, since it does not appear that he used any Injection.

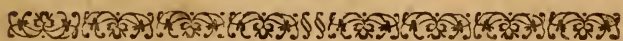
§. 135. All the Veins (§. 153.) dispersed thro' the whole Body are found, like the Arteries, to open into one Trunk, call'd the *Vena Cava* ; which forming a large Sinus, cover'd with Membranes almost like those of an *Artery* ¹, does thereby terminate in the right Auricle and Ventricle of the Heart. But the pulmonary Veins, forming four large Branches, terminate in a Sinus, almost like that of the Cava, which opens into the left Auricle and Ventricle of the Heart. There is also a different

§ 136. *Circulation of the Blood.* 19

rent Mechanism in the Veins of the *Liver* ², which we shall explain when we come to that Viscus. Lastly, These two capital Blood-vessels (§. 134, 135.) are largest at the Heart; from whence they gradually diminish in their Diameter as they pass to the several Parts of the Body, which is generally in close Company with each other. The Area of the Opening of the Vena Cava and its Auricle into the right Ventricle, is to that of the pulmonary Artery opening in the left, as 47 to 114.

¹ By which Coats the Strength of the Cava in this Part becomes almost equal to that of the Aorta: It was necessary it should be thus strong here, to sustain the Weight of the super-incumbent Blood, with an additional Pressure from the Heart in its Systole.

² At this Viscus the splenic and mesenteric Veins unite into one Trunk, which opens into a strong muscular Sinus, from whence the Blood is detached into the Liver by its converging Branches like Arteries, in order for the Secretion of Bile. *Vid.* §. 350.



Of the Circulation of the BLOOD.

§. 136. **I**F any of the larger Arteries of a living Animal be considerably wounded, almost the whole Quantity of Blood necessary to keet it *living* ¹ will be expell'd from thence with a great *Force* ², and in a few
C 2 Minutes

Minutes Time, as we are convinc'd from the common Practice of Butchers.

¹ The Mass of Blood will not indeed be totally discharged by the Wound, because some will remain in the Veins ; for when so much of the Blood's Quantity or Motion is destroy'd as is necessary to keep the Animal living, the Effect is instant Death ; which is the Meaning of *Moses* when he says, that *the Life or Soul of the Brute is in its Blood*, for which Reason he ranks it among the prohibited Food ; but the true natural Reason seems to be, that in those warm Regions the Blood is very speedily apt to putrefy, and afford a Nourishment too alkaline ; yet there may be a religious Reason besides.

² The *Jews*, who are forbid to eat any Animal that is kill'd by Disease, have, from a Tradition of the Rabbins, constantly esteemed the killing by Contusion and Fracture, or knocking down, amongst the Tribe of Diseases, thinking that kind of Death only unaccompany'd with Disease, which is made by Wounding or Incision ; and accordingly when they kill an Ox, &c. they draw up the Head of the Animal to stretch its Throat, which with a sharp and long Knife they suddenly divide so as to cut thro' the jugular Vessels, whereupon the Blood suddenly flows with great Impetuosity to the Quantity of about 30 Pounds, which speedily ends the Life of the Animal. So great is their Superstition in this respect, that the Edge of the Knife must be first tried upon the Nail of the Thumb before they use it ; for if it appears rough or ferrate, the Ox will not be judged eatable. In *Spain* they have nearly the same Method of executing Criminals capitally convicted ; for the Hangman having reclined their Head backwards,

cuts

§ 138. *Circulation of the Blood.* 21

cuts thro' their Windpipe and large Blood-vessels of the Throat. I chuse to offer this Example, because in this Method the Animal does not die apoplectic, as the Oxen do who are kill'd after the common Method of *Europe*.

§. 137. Nor does it much signify in this Experiment (§. 136.) *in which of the Arteries*¹ the Wound be inflicted, as we are assur'd from the *living Dissections of Dogs*², and the Wounds in Men.

¹ Provided it be tolerably large; tho' we have several Instances of fatal Hæmorrhages even from small Arteries, which cou'd not be closed or compressed, as in the Nose, or in the small Artery of a Tooth, &c.

² The Great *Harvey* thus dissected many kinds of Animals with a View of making Experiments. But the present Argument is most elegantly confirmed by an Experiment of *Drelincourt*, who after tying down a Couple of Dogs, made an Incision in the crural Artery of one, and in the carotid Artery of the other, and they both expired nearly within the same short Space of Time.

§. 138. From hence it follows, that all the Blood of the Animal thus wounded, is moved with great Strength and *Swiftness*¹; as will appear more evidently, if all the sound Arteries are secured by *Ligature*², while the Blood flows from the wounded Artery.

¹ Swift indeed, since so large an Animal as an Ox expires by losing 30 Pound of Blood in eight Minutes Time. But the Blood is not moved with

22 *Circulation of the Blood.* § 139.

this Velocity from the Wound, for that has no moving Power to hasten the Course of it ; the Blood must therefore flow thus swiftly from the wounded Artery, because it before moved with a great Velocity within the Arteries ; since in the dead Animal, or one that is dying, it ceases thus to flow.

² For then none of the Blood cou'd pass through the tyed Arteries into the Veins, but it wou'd be all forced thro' the wounded Artery.

§. 139. It is therefore apparent that the Blood has a ready Passage, from every Part of the Body that contains it, into any one of the Arteries ¹.

¹ For all the Blood, except a small Part in the Veins, is discharged from the wounded Artery, (§. 236.) which (§. 137.) may be in any Part of the Body ; so that all the Blood of the Arteries will be evacuated, and the greatest Part of that in the Veins : Therefore the Blood has a ready Passage from all the Arteries of the Body, and also from all the Veins, into any one Artery. There is therefore a free Passage for the Blood out of all the Veins, into all the Arteries ; which Phænomenon contradicts the Opinion of the Ancients, *viz.* that the Blood passes out of the Heart into the Veins, and by them into all Parts of the Body, for Nutrition ; but if the Blood passed by the Veins, as by Arteries, into the solid Parts to nourish them, how should all, or the greatest Part of the venal Blood be discharged by the wounded Arteries. The Phænomenon rather shews, that the venal and arterial Blood are the same ; and that it does not stagnate or extravasate

§ 141. *Circulation of the Blood.* 23

state in the Parts, but is directly carried out of the Veins into the Arteries.

§. 140. Therefore as the whole Mass of Blood flows out impetuously thro' the wounded Artery, it must needs have passed swiftly through the Vessels before the Wound was inflicted.

§. 141. Again, If any Artery be laid bare and tyed with a Thread passed round it, the Artery then swells and beats betwixt the Ligature and the Heart; but becomes flaccid and without Motion betwixt the Ligature and its Extremity, and at the same Time the pervious Arteries adjacent to that which is tyed, are found to beat more violently: If now the Artery be incised betwixt the Ligature and the Extremity, little or no Blood follows; but if you open it betwixt the Ligature and the Heart, it continues to send out a swift and starting Jet of Blood till the Animal expires. But the Artery for this Experiment ought to be single, or by itself, and without any Communication beyond the Ligature, by *Anastomosis* ¹, with any other adjacent Artery.

¹ Of which kind there are usually many Communications of the Arteries in the extreme Parts of the Limbs. By such *Anastomosis* it may indeed happen, that the Blood passing out of the free into the tyed Artery, it will flow out beyond the Ligature, if the *Anastomosis* was beyond it; for which Reason a Ligature is order'd

24 *Circulation of the Blood.* § 143.

to be made above and below the Artery in the Operation for an Aneurysm. The carotid Arteries have also frequent Communications or Anastomoses with each other, and with the cervical or vertebral Artery; so that upon tying or wounding either of them, the Blood will pass out of one into the other.

§. 142. From whence it appears, that the Blood in a living Animal, has not only a Motion in the Arteries, but also that its Motion or Flux is directed from the Heart to the Extremities, and that it is distributed to all Parts remote from the Heart both external and internal by these Vessels; so as to pass from the Trunk to the Branches, or *from a greater Diameter to a less*¹; and in this manner the whole Mass of Blood may be derived into and discharged from any one of the Arteries, but not the contrary way.

¹ That the Blood takes this Course as well in the smallest Arteries as in the larger Trunks, is also apparent to the very Eye, when armed with a Microscope, according to the Demonstrations of *Lewenboek*.

§. 143. If any one of the larger Veins be in like manner (§. 141.) laid bare and tied with a Thread, it swells betwixt the Ligature and the Extremity without any Pulsation, but appears empty and flaccid betwixt the Ligature and the Heart: If now the Vein be opened betwixt the Heart and Ligature, little or

or no Blood follows, but if incised betwixt the Ligature and Extremity, the Blood continues pouring out till the Animal either faints or dies. Nor is one Vein of more Consequence than another for this Experiment, as we are assured from *Phlebotomy* ¹.

¹ In this Operation, upon making a Ligature on the Arm, betwixt the intended Orifice and the Heart, the Blood is accumulated in the Vein, and runs out faster from the Wound; but it is not the Blood in the Hand only which is thus let out, for that Part weighing not much above a Pound, is incapable of yeilding near two Pounds of Blood. We have indeed an Objection made by some, which is no more than a Falacy: *viz.* That when the Ligature has been made a while on the Arm in Phlebotomy, the Blood frequently ceases to flow from the Vein thus incised; which they think argues against the Blood's moving in the Veins from the Extremities towards the Heart. We know that this Accident does sometimes happen in Bleeding, but then it proceeds from the Arteries lying too bare, or the Ligature being too tight, so as to compress the Artery as well as the Vein, by which means the Blood cannot pass out of the former into the latter; which therefore does not appear at all distended, and yields no Blood from its Orifice; but so soon as you slacken the Ligature, the Blood follows plentifully.

§ 144. It therefore follows, that the Blood flows swiftly from all Parts of the Body into the incised Vein; and that the Direction of its Course in the Vein is from the lesser to the larger

26 *Circulation of the Blood.* § 132.

larger Diameter of the Vessel, from the Branches to the Trunk, or from the Extremities towards the Heart : And that the Blood moves thus and no other way in the Veins, is also apparent from the Valves. (§. 133.)

§. 145. Hence it is sufficiently evident, that the vital Blood is continually carried with a swift Motion thro' all the Arteries of the Body, and that its Course in them is from the left Ventricle of the Heart thro' the Trunk of the Arteries into their Branches, and by these into all Parts of the Body, both external and internal.

§. 146. But on the contrary, all the Veins, except the Porta in the Liver, return the Blood constantly from all Parts to their Branches, and from their Branches into their Trunks, from whence it passes in the right venous Sinus, and partly into the right Auricle.

§. 147. For the Blood brought into the venous Sinus may be drove from thence, by its muscular Coat into the right Auricle, when relaxed ; since there is then no Resistance, and its Progression is forwarded by the Impetus of the subsequent venal Blood urged on to that Part.

§. 148. But since both the right and the left Auricle of the Heart is each of them a large hollow Muscle, furnished with many small Arteries and Veins, and composed of two Rows of strong Fibres running in contrary Directions into opposite Tendons on each Side ;

§ 149. *Circulation of the Blood.* 27

Side; one Tendon of the right Auricle being inserted into the venous Aperture of the right Ventricle, and the other Tendon, which is firmer, terminating circularly round the Cava; it is apparent, that by the contractile Force of this last, the Blood may be expelled with a considerable Impetus into the right Ventricle, when relaxed.

The right Auricle is near ten Times larger than the left; but then the right Sinus, or that of the Cava, is much less than the left Sinus of the pulmonary Vein; the Reason of which seems to be founded on the Office of the Auricles, being partly to attenuate the Blood, or prevent its Concretion: For the Blood in the right Auricle being less fluid than that which has passed the Lungs, it was necessary that more of it should suffer the Action of the Auricle at the same time; whereas the left Auricle being less than the right, is accompanied with a larger venous Sinus, that it might be able to receive the same Quantity of Blood which was discharged from the right Auricle and Sinus together.

§. 149. For the right Ventricle of the Heart being then empty becomes longer, and the three tricuspid Valves are drawn back towards the Sides and towards the Apex of the Heart, whose two muscular Sides of the right Ventricle, from whence those Valves arise by round muscular Processes or Papillæ, are at the same time dilated or moved back to each Side, so that a Passage being thus opened to
the

the Blood, there remains no Obstacle to hinder it from taking this Course.

The tricuspid Valves are confined to their Seats in the Heart by the muscular Processes and tendinous Cords which ascend out of its Apex; whence it happens, that when the Heart is elongated, these Valves are drawn down towards its Apex and Sides, by which means they make a free Passage for the Blood into the right Ventricle.

§. 150. What we have here advanced is also confirmed by Inflations, Injections, the anatomical Structure of the Parts, and their Appearances in living Dissections.

That these Parts act in the Manner before described, may be made appear even to the Eye by opening a living Dog; and if you blow Wind by an Incision into the right Ventricle, it will not distend or pass into the Cava, because by elevating the tricuspid Valves, its Passage thither is excluded.

§. 151. The right Ventricle being thus filled with Blood, does, by the Contraction of its Fibres, also press out the Blood from the coronary Veins which open into this Ventricle, and mixing them together, continues to urge the same strongly in all Directions, and particularly towards the Apertures of its Cavity; by this Means the Blood rising up by the Sides of the same Ventricle, catches hold of, and elevates the tricuspid Valves, which are so connected

§ 151. *Circulation of the Blood.* 29

ned to their fleshy Columnæ on each Side, that they cannot be quite closely approximated even with the Sides of the right Ventricle; the Valves are therefore thus pressed by the Blood towards the right Auricle, till they meet close together, and by occluding the Passage, *entirely prevent its Return*: For the Columnæ of the Valves will not permit them to be pressed farther back than to meet, and the venal Blood returning from the whole Body also supports them on the other Side; so that by these means the Contraction of the Heart, tho' strong, cannot urge the tricuspid Valves too far back towards the venous Sinus ².

¹ For the stronger the Blood is urged towards the Cava by the Contraction of the right Ventricle, the farther are the tricuspid Valves thrust out, and more closely approximated by the same Means; and when the Valves have had their greatest Distention, which is but small, except the pulmonary Artery be obstructed, this last is then immediately open'd, and a Passage thereby made for the Blood to enter into the Lungs. In the mean time, while the right Ventricle is contracting, the venal Blood is collected in the right Sinus and Auricle against its Relaxation, when, depressing the Valves, it passes into the right Ventricle by Pressure, its own Weight and the Force of the succeeding Blood in the Veins.

² When the Heart is relax'd and receives the Blood, its muscular Flesh at that Instant appears intensely red; because at that Time all its coronary Arteries and Veins are turgid with Blood, drove into them by the Contraction of the Aorta: But when the Heart is in its Systole or Contraction, the

the Blood before received into the Vessels of its muscular Substance is then expressed and discharged by the larger coronary Veins, which open into its right Sinus and Auricle; and Part of the Blood is also expressed thro' the exhaling Veins which open in every Part of the right Ventricle, by which means the Heart at that Instant becomes pale and bloodless. Nor is it improbable, that the Blood in the larger Trunks of the coronary Arteries returns again at that Time into the Aorta by their Orifices which arise from thence. In Fish, this alternate Change of Paleness and Redness in the Heart is very conspicuous, since they have but one Sinus, Auricle and Ventricle, one Vein and one Artery. In them the venous Sinus first becomes turgid, then the Ventricle, and then the Artery, which is turgid in its Repletion; and at the same Instant the Sinus also becomes turgid and red.

§. 152. By this Contraction of the right Ventricle, (§. 151.) the same Blood is also forced up against the three semilunar Valves, attached to the Margin of the other Aperture of this Ventricle, in the Entrance of the pulmonary Artery; and by pressing those Valves against the Sides of their Artery, forces itself a Passage into that Vessel only.

§. 153. But such is the Structure and Connection of these Valves, (§. 152.) that it is evident they are fill'd out and meet together, by the Reaction of the Blood in the pulmonary Artery towards the right Ventricle, so as to intercept its Return, since they close more exactly, as the Blood endeavours to return more forcibly. But at the same Time that these Valves are
shut

§ 156. *Circulation of the Blood.* 31

shut and distended by the Blood in the pulmonary Artery, they are also then supported on the other Side by the Blood drove out of the venous Sinus into the Cavity of the Ventricle; by which means they are preserved from being broke or over-strained by the Repulse of the Blood urged by the Contraction of the pulmonary Artery.

§. 154. All this (§. 151 to 154.) is proved not only from the Structure of the Parts, but also by Observation in living Dissections, with Arteriotomy and Injections.

§. 155. It therefore follows from hence, that the venal Blood coming from all Parts of the Body, (§. 146.) continually passes with a quick and strong Motion out of the venous Sinus, thro' the right Auricle and Ventricle, into the pulmonary Artery alone.

§. 156. In the next Place the Blood passes from the Artery into the pulmonary Vein, and left venous Sinus, formed by the meeting of the four large Branches of that Vessel; by the muscular Fabric of which Sinus the Blood is thence pressed into the relaxed Cavity of the left Auricle, which is much less than the right, tho' it has the same Structure and Position. From the Auricle it passes (§. 148.) into the left Ventricle, when relaxed; into which it may readily enter by its two *mitral Valves* having the same Mechanism as the *tricuspid*s before, (§. 149, 150.) which also prevent it from returning back the same Way, (§. 151.)

As

32 *Circulation of the Blood.* § 158.

As the left Ventricle contracts with a much greater Force than the right, and exerts proportionally a stronger Pressure against the Valves to shut them when it protrudes the Blood into the Aorta, there was here no Need of three Valves at the Entrance of the pulmonary Vein, two being sufficient, which have a narrow Opening into the left Ventricle, like a Slit; to close which with the greater Resistance, when the Heart contracts, the membranous Sides of the Valves are wrapped over each other, and form as it were a double Partition.

§. 157. The Blood protruded into the Aorta by the right Ventricle, is determin'd strait forwards in that Vessel by the *three semilunar Valves* ¹ placed at its Entrance, (as §. 152, 153, 154.) and this more especially when the Artery contracts, at which Time the Blood reacting on the Valves, closes them very exactly. But what has been hitherto said, relates to the Course of the Blood in Adults, and those of our Species who breathe in the usual manner: As to its Circulation in the Fœtus, see §. 680, & *seq.*

¹ Which have been also denominated Sigmoides, from their Resemblance to the old Sigma of the *Greeks*, which was shaped like our Roman C.

§. 158. Hence it is evident, that all the Blood of the pulmonary Artery passes by the Vein into the left venous Sinus, thence into the left Auricle and Ventricle, and thence into the Aorta; and thus continually, with a strong and swift Motion.

At

§ 159. *Circulation of the Blood.* 33

At that Instant when the right Ventricle of the Heart is contracted, it does not admit any of the Blood from the Cava; it must then be accumulated there, so as to fill the right Sinus and Auricle, as it also must in the left Sinus and Auricle: But when the Ventricles of the Heart are relaxed by the Depletion of their coronary Arteries, and Compressure of their Nerves, the contractile Force of the venous Sinus's which they continually exert, will then overcome the Resistance of the Heart, which as a relaxed Muscle will be no more than its Weight; and thus the Ventricles will be filled with the Blood that was till then collecting in the Sinus's. At the same Instant of Time that the Ventricles are thus filling, the coronary Arteries will be also filled by the Aorta; and when the Aorta and pulmonary Artery are contracted, or at rest, the cardiac Nerves will be then free from Pressure, the two Causes of Motion in the Heart will be thus renew'd, and its former Contraction must follow. Hence the perpetual Motion of the Heart.

§. 159. This Motion or Course of the Blood before described, may be distinctly observed in *living Dissections*, and is then attended with the following Phænomena.

1. Both the venous Sinus's are filled, become turgid and red at one and the same time; and so are both the Auricles.

2. Both the Auricles become flaccid at the same Instant, and so do also the two venous Sinus's.

3. In the very Moment that the Auricles become flaccid, they are then fill'd with
D Blood,

Blood, by the Impulse of that in the Veins, together with the muscular or contractile Force of the venous Sinus's.

4. At the very Instant when the Auricles are thus fill'd, both the Ventricles of the Heart contract themselves at one and the same Time; in which Action they become pale, and discharge their contained Blood into the two large Arteries, which are thus filled and dilated.

5. The Moment after this Constriction of the two Ventricles, they become empty and flaccid, are *elongated*² and enlarged, and appear red.

6. The last Appearances are no sooner observed, but the two Auricles and muscular venous Sinus's contract with a muscular Force; by which they discharge their contained *Blood*³ into the empty Ventricles of the Heart, and in this Action the Auricles look pale.

7. In the mean time the venous Sinus's will be again filled, and then the Auricles, as we first observed: And in this Order will all the forementioned Appearances return again, and be continued in the same Series, till the languishing Animal is near dead⁴.

8. But when Death approaches, the Auricles and venous Sinus's beat several times to one Contraction of the Ventricles⁵. At length, the left Ventricle first ceases to move, and then its Auricle; afterwards the right Ventricle is still, and last of all the right Auricle. The Animal is now dead, after which
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§ 159. *Circulation of the Blood.* 35

we find the left Ventricle empty, but the right Ventricle always full of Blood.

¹ These Appearances are best remarked in the Dissection of young Whelps or Kitlins, soon after their Birth ; because these live much longer without breathing, after the Thorax and Pericardium have been open'd.

² Injecting the Heart with warm Water fills its Ventricles, and renders them longer ; but upon pressing the Apex of it towards the Basis, the Water passes out into the Arteries.

³ This Force is equal to that with which the Heart impells the Blood into the Arteries ; otherwise, if the Force was but little less, the Blood would return more slowly to the Heart, which would consequently send it more slowly into the Arteries ; and this small Difference increasing every Minute, there would at last be no Blood impell'd into the Heart, which would therefore cease to move.

⁴ Upon wounding the carotid Artery of a living Dog, the Blood spouts forth like the Jet of a Fountain ; but growing gradually weaker, it at length starts out only at Intervals, till at last the Flux totally ceases. In this State the Heart of the expiring Animal is found still and contracted, yet the Auricles continue to beat or contract weakly and at longer Intervals, till at length the Ventricles being filled, the Heart with a sudden Start contracts itself again ; but this Systole being over, the Heart remains flaccid and without Motion for a Minute or two, and as long an Interval passes before the Animal breathes : Thus the Heart continues longer and longer at rest each Time, till there is Blood enough accumulated in the Sinus's and Auricles to overcome the Resist-

ance of the Ventricles. At length the muscular Force of the right Ventricle becomes too weak to overcome the Resistance of the Lungs, and therefore contracts no more, which makes the Death of the Animal. But even after this the Blood continues to move towards the Heart in the Veins, being propelled by the Contraction of the Vessels assisted by the Cold, which follows Death. At last the right Ventricle being dead, the Auricle only palpitates; and when that is still, there only remains a small Motion for a Time in the Cava near the Heart.

^s It has been long ago observed, that the Motion of the Auricles in the Heart remains after that of the Ventricles; and the Fact is also demonstrable to the Eye by opening the Thorax of a living Animal. But what is more extraordinary, both the Auricles and Ventricles of the Heart may be restored by Art to their former Contractions even after they have ceased to move, or when the Animal is really dead. Thus *Peyerus* and *Wepfer* demonstrate, that by blowing into the thoracic Duct, or into the Vena Cava so as to urge forward the Blood, the Heart of the dead Animal will by that means renew its Contractions; as it also will barely by pressing hard on the Thorax, tho' the Spectators might imagine this to have the contrary Effect. This seems to have been the Case with the great *Vesalius*, who was banished for opening a *Spanish* Nobleman before the Heart had done moving. So that if the Heart deserves the Title of *ultimum moriens*, the right Ventricle and Auricle are the most deserving of it, as they move longer than the left; but the Cava last of all. Nor is it at all strange that the right Ventricle, which is the weakest, should move longer than the left; for Respiration ceasing,

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§ 160. *Circulation of the Blood.* 37

the Blood cannot pass thro' the Lungs to fill the left Ventricle, tho' the right be at the same time plentifully supplied: For which Reason we usually find in People who die suddenly, that upon opening them, the right Ventricle is full of Blood, while the left is empty.

§. 160. From what has been said, it therefore appears that all the Blood returning from every Part of the Body, (as well external as internal, not excepting that of the Heart itself and its Auricles) is drove into the right Ventricle of the Heart, out of which it is forced thro' the Lungs into the left Ventricle, and from thence by the Arteries thro' every individual Part of the Body, from whence it returns by the Veins to the Heart again. This is the uninterrupted Course of the Blood's *Circulation* ¹, the Glory of which Discovery, with the Proofs and Explanation of it at large, is due to the immortal Name of Dr. *Harvey* ²: The Truth of which Circulation is also confirmed by *Injections*, ³, *Transfusions* ⁴, and even to the Eye itself by the *Microscope* ⁵.

¹ We have hitherto demonstrated a threefold Humour returning to the Heart, *viz.* the venal Blood, the Chyle poured into it by the thoracic Duct, and the several Juices absorbed by the bibulous Ducts throughout the Body, which lead to the Veins. This mixt Fluid of the Veins is received into the right Ventricle of the Heart, which forces it into the Lungs, and thence into the left Ventricle, which propels it thro' all Parts

of the Body by the Arteries. As the Truth of this System is founded on Experiments, by which we are let into the Bosom of Nature, let us gratefully acknowledge to whom we owe the first Revelation of this important Truth. The System of the ancient Physicians is, “That the Blood
 “ passes from the Heart as well by the Veins as
 “ the Arteries, the nutritious Part of it by the
 “ former, and the more spirituous by the latter;
 “ but that nothing returns to the Heart more
 “ than a Chyle, absorbed by the mesenteric
 “ Veins, and by them conveyed to the Liver,
 “ where it is first concocted and puts on the
 “ Nature and Colour of Blood, before it goes
 “ to the Heart.”

² *Hippocrates* has had the Honour given him of knowing the Circulation, first by *Riolan*, and then by *Drelincourt* and others; but it is certain, that if he understood the Blood's Motion, he has expressed himself so unintelligibly about it, that his acutest Interpreter, *Galen*, did not thence so much as suspect that the Blood had a circulating Course. But we are well assured, that the first Author who taught “that the Blood of the Vena Cava did
 “ not pass thro' the Septum Cordis into the left
 “ Ventricle, but that it arrived thither by a long
 “ Course thro' the Artery and Vein of the Lungs,” was one *Michael Servetus*, a *Spanish* Physician, in his very scarce Book, *De Erroribus Trinitatis*, publish'd at *Basil* in the Year 1531. The same thing was soon after proposed by *Columbus* in a manner so much alike, that one of them seems to have taken it from the other. After these, *Caesalpinus* had much the same Notion, and also imagined that the Veins did not convey the Blood from, but to the Heart. All these seem to have had a distant View of the Blood's true Course, but in
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part only ; so that as they did not understand or explain the whole, and confirm it by sufficient Proofs, the great *Harvey* has still a just Title to the Invention or Discovery : For by an Inventor we understand one, who is not only acquainted with the Thing he proposes, but who also demonstrates or explains the same, so that all Men of Learning may be convinced of and comprehend it ; but this was first done by Dr. *Harvey* only, who has supported his System with innumerable Experiments, and has by that means given more Light into all the Branches of Physic than we have ever receiv'd from any other anatomical Discovery. We are even bound to acknowledge the high Merits of this great Man, to whom we all owe a profound Veneration ; because it is upon his System only, that we can obtain any just Notions either in the Theory or Practice of Physic, which have by this means been purged from Fiction, and founded on the true Basis, which is equal to the Dignity of the Profession.

³ In 1656, *Wren* and *Lower* first injected Liquors into the Veins of Animals ; since which Time we have had various medicinal Liquors injected into the circulating Blood of Men, which have produced the very same Effects throughout all the Vessels of the Body, as if a larger Dose of the same Medicine had been taken inwardly,

⁴ In 1658, Dr. *Henshaw* discover'd a Méthod of transfusing the arterial Blood of one Animal into the Veins of another ; which Experiment was afterwards improv'd and publish'd by Dr. *Lower*, (*de Corde*) Ann. 1665. The Blood of the emittent Animal being hereby exhausted, it expires, while the Recipient continues alive and well. To do this, let two Dogs be tied down near each other upon the same Table ; then denudate and tye the

carotid Artery of one, and the crural Vein of the other, and after making an Incision in the Carotid betwixt the Heart and Ligature, insert a Tube, whose other End is to pass by an Incision into the crural Vein of the other; and thus the Blood will pass into the Veins of the last Dog, till the first expires. This Experiment seems to have been first hinted by *Libavius*; and tho' Dr. *Lower* was undoubtedly before-hand with Mons. *Devis* in the Trial of it on Brutes, yet the *French* first tried the Transfusion on Men. The Experiment was soon received with great Applause both thro' *France* and *England*, and great Things were expected from it in the Cure of Diseases, and the Recovery of Youth, since they cou'd now convey the Blood of a sound and young Animal into a Man that was old or diseased, and by that means procure the Longevity talked of by the Alchemists from their Elixir or Stone. But in a little Time all these Expectations disappear'd, and the Experiment was prohibited to be made on Men by the public Law. For a *Swedish* Nobleman being given over by his Physicians in an ardent Fever, one of them was willing to take the Advice of *Hippocrates*, to make Trial of an uncertain Remedy in a desperate Case. Accordingly an Exchange is made, by Transfusion, of a few Ounces of the Patient's Blood for a Quantity of that from a sound Animal; the Experiment succeeds, and the Patient is much better, insomuch that Transfusion becomes esteem'd and admir'd by the whole Court of *France*; it must therefore be repeated, since the Patient's Blood does not yet move slow enough: But very unfortunately the noble Patient expires even in the Experiment, and becomes a Victim to the Curiosity of Physicians. Hereupon Transfusion comes into Disgrace, is prohibited by Parliament, and meets with

§ 162. *Circulation of the Blood.* 41

with such universal Neglect, that at present we hear not the least Talk of it.

The Blood's Circulation was discover'd to the Eye by the Microscope in 1661, by *Malpighi* and *Lewenboec*. The latter saw it pass out of the smallest Arteries into the continuous Veins. But the old Gentleman was so infatuated or misled by his Experiment, that, contrary to every body's Opinion, he thought the Veins had a Pulsation, and that the Arteries had none. This Error seems to have arose from the retrograde Course of the Blood in many of the evanescent Arteries, as some of their Anastomoses contract and are obstructed in the dying Animal, so that the Blood moving the same Way both in Arteries and Veins, has made me sometimes look seven or eight Minutes without being able to distinguish one from the other.

§. 161. It also follows that the Chyle, (§. 126.) being continually pressed in a small Quantity thro' the thoracic Duct (§. 125.) will so far open the Valves in the subclavian Vein, (§. 124.) (which are always kept shut by the opposite pressure of the Blood) as to admit a Quantity of Chyle, which by its Weight is able to overcome the Resistance of the Blood in the same Vein, thro' which it will descend, together with the Blood, into the Cava and its Sinus, and thence into the right Auricle and Ventricle.

§. 162. The Chyle being plentifully diluted with the returning Lymph, and thus continually mixing in a small Quantity with the Blood, and that running together from the Veins in opposite

42 *Circulation of the Blood.* § 163.

posite Directions ¹, does not only preserve them from coagulating in the Cava, but makes the first Mixture of the Blood and Chyle there.

¹ The right and left subclavian Vein open into the Cava in opposite Directions ; so that the Blood of the right Subclavian, which has none of the Chyle, mixes with the opposite Stream of the left Subclavian, charged with the Chyle. About the same Part the jugular Vein also opens after it has descended perpendicularly, and conveys the Blood diluted with all the Lymph separated in the Parts of the Head, and with the moist Vapours which part the dura Mater, and pia Mater from each other, and the latter from the Brain itself. Thus the Blood meeting from the Veins in opposite Directions occasions an intimate Mixture. And in the way, before the Blood of the Vena cava passes to the Heart, it meets with that of the Vena azygos, which ascends thro' the whole Thorax ; from all which, and many more Veins of different Courses, the superior Trunk of the Cava receives its Blood before it passes to the right Auricle and Ventricle of the Heart.

§. 163. The Blood and Chyle being in the next place drove into the furrow'd Cavity of the Auricle, is there, by its forcible Contraction, and the opposite Concussions of its muscular Columnæ on every Side, still more intimately mixed, divided and render'd *Fluid* ¹, also the Mixture and Fluidity is render'd still more perfect by the Occursion of the ¹ Blood that *slips thro' the Auricle* ², togeth with the Blood returned into the Cavity of the Auricle

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Auricle from the Substance of the Heart by the coronary Veins ; which last is doubtless discharged with a considerable Force, and render'd very fluid by the muscular Contraction.

¹ The Blood of a healthy Person coagulates into a solid Cake barely by standing still a little while ; but when the Auricles of the Heart contract, the Blood in the adjacent Veins and their Sinus's must of Necessity stop, and wait till the Auricles are relaxed, and till more Blood succeeds from the Veins : The Blood of the large Veins is therefore in the greatest Danger of coagulating, if that was not prevented by a plentiful Dilution with Lymph ; and by the Concussion of the Auricles, which having a rough Surface, do by their muscular Columnæ attenuate the Blood, and blend it with the Chyle.

² It is not probable that all the Blood which enters from the Sinus's into the Ventricle of the Heart, is first retained in and sent thither by the Auricles ; for in the left Ventricle there is not room enough to hold all the Blood which comes from the Lungs ; and therefore it is probable, that when the Auricle sends its Blood in the Ventricle, some Part of the Blood will then slip from the Sinus directly into the Ventricle, without being at all retained in the Auricle. The Quantity of Blood which thus slips thro' the Auricle from the venous Sinus into the right Ventricle, does not seem to be more than a tenth Part of what the Auricle will contain, because the Proportion of the Sinus to the Ventricle is not larger,

³ All the Blood of the Heart itself is discharged by the coronary Veins, either into the Sinus of the Cava, the right Auricle, or else the right Ventricle. But this Blood is more agitated, warm and fluid than that of any other Part ; and therefore

44 *Circulation of the Blood.* § 165.

fore it may render the other Blood, with which it mixes in the Auricle, more thin and fluid than it otherwise would be.

§. 164. But what Alteration or Impression is made on the Blood and Chyle by the Action of the Heart, can be understood only from the Structure of that Organ and the Nature of the Blood; in our Enquiry after which, we ought to rely only upon solid Experiments, such as we shall presently mention, since the Subject has afforded much Controversy, and several Hypotheses¹.

¹ The Opinion of the Ancients was, that the Blood passed from the Liver into the right Ventricle of the Heart; and that from thence it went in part into the pulmonary Artery to nourish the Lungs, and that the other Part transfused thro' the muscular Septum of the Heart into the left Ventricle, where, mixing with the vital Spirit from the Lungs, it became arterial Blood. And in the last Century the Chemists and Followers of *Sylvius de la Boe* supposed the Blood in the Heart of an alkaline Nature, and that it fermented with the other Blood, which abounded with an acid Chyle and pancreatic Juice. *Cartesius* supposed the Blood to enter the Heart by a Drop at a time, which by intense Heat so rarified as to distend the Heart, and then ran out boiling into the Lungs to be cooled.

§. 165. The Blood contained in the right Ventricle of the Heart of a fasting Animal does not taste either *alkaline*¹ or *acid*², but *brackish*³, like that of Sea-salt, or Sal-ammoniacum.

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¹ That healthy Blood is free from any alkaline Acrimony, may appear not only from its having no such Taste, but also from its giving not the least Pain to wounded Parts, nor even to the Eye itself, if dropt into it; nor does it manifest any Fermentation with Acids, nor turn the violet-colour'd Tincture of Flowers green as alkaline Salts do.

² An acid Acrimony is still infinitely more remote from the Blood, since its natural Tendence is to Putrefaction, after Rest.

³ This Brackishness is in the Blood of People who eat much Sea-salt; but in Brutes which are not domestic, it is almost insipid.

§. 166. If the Blood be mix'd either with Acids or Alkalies, it does not afford any apparent Motion of Fermentation, but it thereby receives some Change in its *Colour*¹ and Degree of Fluidity. Indeed Oil of Vitriol, which is distill'd by the most intense Fire, and highly rectified, makes an Effervescence with the Blood, as it does with all other Liquors, especially the oily.

¹ With *Oleum Tartari per deliquium* the Blood becomes turbid, and of a fiery Colour; with *Sp. Salis ammoniaci* it becomes thin and fluid, and of a florid Colour; with several Sorts of Vinegar it preserves its Fluidity; but with Spirit of Nitre and other mineral Acids, it coagulates; yet it does not produce any Ebullition with either of these; and tho' it will make an Ebullition with highly rectified Oil of Vitriol, 'tis only from the Water in its Composition, which, whether alone or in any other Liquor, is most powerfully attracted by
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that strong Acid. Some tell us, that as both an Acid and an Alkali is obtained by distilling the Blood, therefore both of them must be naturally in its Composition; whereas they are both in reality the Produce of the Fire. Others endeavour to evade our Argument by saying, that the lixivial Salts in the Blood are naturally such as will not ferment with an Acid: If so, how do they appear to be lixivial? for we are no otherways assured that an alkaline Salt exists in any Body, but by the Phænomena or Effects it produces therein; and when those Effects are not to be found, we must reasonably conclude the Cause or Alkali to be absent.

§. 167. The Blood which starts out from a Wound in the pulmonary Artery, being received into a Vessel, does not afford any Signs of an intestine Ebullition or Effervescence, but yields a sharp and *ill-smelling*¹ Vapour; and after standing in the Cold, it congeals, and then separates into two Substances, one of which is more compact and solid than the Mass of Blood itself, and the other is ferous and more fluid.

¹ This is a rank Smell, coming betwixt the Odour of Sweat and Urine, and which is hardly perceptible in the Blood of an Ox.

§. 168. If the Apex of the Heart in a living Animal be cut off, and you then turn it upwards, you will perceive the Blood to be drove by the Auricle into the right Ventricle, when the first contracts; but this without any
Ebul-

§ 169. *Circulation of the Blood.* 47

Ebullition or Fermentation, as you will more distinctly perceive towards the Death of the Animal. And all these Phænomena (§. 165 to 169.) are also true in the Blood of the left Ventricle.

§. 169. If a *Thermometer*¹ be thrust into the Heart of a living Animal, it does not discover that the Blood has a greater Heat there than in the other Viscera. At which we need not wonder; for if, from the Difference of Velocity and Attrition, the venal Blood returns something cooler than the arterial, as they both meet in the Heart, they will be there of the same Temperature.

¹ Several Experiments of this Nature were made so early as 1666 by *Malpighi*, *Borelli*, and others. They opened both the Heart and the Limbs of the same Dog, and upon inserting a Thermometer into the Ventricle and into the crural Artery, they found that both the Instruments indicated the same Degree of Heat. Those who embraced the Hypothesis of the Ancients, objected, that as the Heart was universally allow'd to be the Fountain of Heat, they cou'd not see why the Blood in that shou'd not be hotter than in the Limbs. It is indeed certain, that as the Blood moves slower, and with less Attrition in the Veins than the Arteries, it wou'd be cooler in the former than in the latter, if they did not take the same Course, and run close to each other. And as the greatest Share of Motion and Attrition is communicated to the Blood by the Heart and Lungs, it wou'd be proportionably hotter in those than in the other Viscera, if it was not to communicate Part of its Heat to the colder Air in the Lungs;

Lungs ; which Communication of Heat from the pulmonary Blood to the Air is very readily made, both from the Thinness of the Membrane which parts 'em, being ten times thinner than writing Paper, and from its vast Extent or Surface within the Lungs, being computed more than the Surface of the whole Body. But as the external Air is always colder than the Blood, it will by Contact with the Lungs become warm ; so that in the Winter time it may be blowed out warm, agreeable to the Fable of the Satyr. But as much Warmth as the Air gains in the Lungs, so much must the Blood lose there ; upon which account, in a hot Air we pant, or breathe more frequently ; that by oftner changing the warm Air, which does not take off so much of the Heat of our Blood, we may bring it to the same Temperature, as we might by fewer Respirations of a colder Air.

§. 170. The Taste of the Chyle in the thoracic Duct is generally that of *Sea-salt*¹, or the Flavour which was predominant in the *Aliments*².

¹ *i. e.* When it has not the sweet or milky Taste at §. 127.

² Thus the Smell and Taste of Onions, Garlic, Asparagus, Turpentine, &c. may be not only perceived in the Chyle, but also in the Nurse's Milk, in the Sweat, Urine, &c. even the Colour and medicinal Qualities of some Things are also extended in the same Manner, as Rhubarb, the Machine le apple, &c. and even Madder tinges the very Bones. See *Phil. Trans.* N°. 442, and 443. Hence, if ever there be any Acid or Alkali in the Blood, 'tis that of the Chyle or Aliments not yet digested, and will be always too mild to yield any Taste or Fermentation.

§. 171.

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§. 171. The same Chyle taken from the Duct, and mixed with Salts of an opposite Nature, hardly ever makes the least Ebullition.

§. 172. If the same Chyle be received into a clean Vessel, it is never observed to have any Motion of Fermentation or Ebullition.

§. 173. Nor is any such Motion apparent in it, whilst remaining in the thoracic Duct.

If you open the Thorax of a Dog, and close the wounded Vessels with Vitriol, you may then plainly observe with your Eye, that the Chyle passes thro' the thoracic Duct into the Blood of the Subclavian without any manner of Froth, Luctus, or Ebullition either in the Duct or Vein.

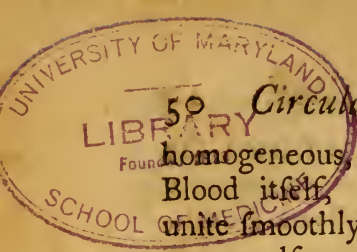
§. 174. Nor does the Chyle make any Ebullition or Fermentation during its Stay in the thoracic Duct, nor when it is drove from thence into the Subclavian, nor when mixed with the Blood in the Cava, or the Auricle and Ventricle of the Heart.

§. 175. Nor does it appear to make any Ebullition, if you intercept its Course by making a Ligature in the Subclavian betwixt the Valves and the Cava.

§. 176. And lastly, as the Chyle is mixed in its Course with a vast Quantity of Lymph from the conglobate Glands (§. 105.), which is separated from the arterial Blood, and poured either into the Chyle itself, or into the venal Blood with which it mixes, it will from hence follow, that the Chyle must be nearly

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50 *Circulation of the Blood.* § 177.

homogeneous, or of the same Nature with the Blood itself, with which it must therefore unite smoothly, and without any Luctus, as we are also convinced it does by Experiments.

Sylvius de le Boe, to support his System of Fermentation betwixt the Blood and Chyle, taught, that tho' the Blood itself was not acid, yet the Lymph thence separated became so by stagnating in the conglobate Glands, and mixing there with an acid Spirit secerned from the Blood. But, on the contrary, (1.) the Lymph, when left to itself, always turns putrid or alkaline, and not acid, as it ought to do on his Principles: And, (2.) the Chemists have never yet produced an Instance of an alkaline Substance turning acid, which is a Change the least of all to be expected from Stagnation or Rest.

§. 177. It therefore follows, that there is no *Fermentation*¹, *Effervescence*², or *Ebullition*³ produced in the Heart, either from the Organ itself, or the mixed Fluid which enters it; and therefore we cannot expect, nor find any of the *Effects*⁴ of such Motions.

¹ Fermentation is that apparent intestine Motion in the Parts of Liquors at Rest, which generates many Air Bubbles, and produces an acid and inflammable Spirit. Thus new Wort made without Hops will ferment to such a Degree as to run all into Froth, which if confined will often burst the including Vessel, with so much Violence as makes their Parts fly to an incredible Distance. But the Blood does not come into the Class of vegetable Liquors, to which this Operation is restrained,
nor

nor is there a Possibility for it to fervent. Nor does it ever generate Air, even by its most violent Commotions in ardent Fevers, so as to burst its including Vessels.

² Effervescence is a Name we give to the Noise, Rarefaction, and ascending Air-bubbles, produced by mixing two Liquors before at Rest. That there is no such Commotion in the Blood we are convinc'd, (1.) from the Absence of the Causes, since it never contains opposite Salts (acid and alkaline) of that Strength or Quantity sufficient to make any sensible Luctus. (2.) From the Absence of the Effects, since we cou'd never observe by any Experiment, such a Motion in the Blood either within or out of its Vessels. It has indeed been asserted by *Homberg*, and some other *French* Gentlemen, that there may be a latent Effervescence in the Blood, not sensible to the Eye; and for an Instance, that such a latent Effervescence is possible, they bring a Mixture of Spirit of Nitre with Cantharides, in which we observe no Luctus while the Air has a free Admission; but so soon as the Bottle is corked, a Commotion arises in the Mixture, by which the Cork is drove out with a considerable Force, and that even if the Mixture has stood by for some Years. In Answer to this, we readily grant that there may be such a Luctus or intestine Motion in the Parts of the Blood as is not sensible, especially if it stagnates; but then it ought not to be termed Fermentation or Effervescence, which is a sensible Phænomenon; nor do we allow it to be productive of the same Effects.

³ This is such a Motion in Liquors as causes them to boil up strongly, and discharge great Bubbles of Air. Such an Appearance we observe in Water heated, so as to raise the Thermometer above 180 Degrees. That there is no such Ebul-

lition of the Blood in the Heart, we prove by Experiment: For upon opening the Thorax of a Dog, and inserting your Finger by an Incision into the Heart, you will feel a Constriction in its Systole, but no Rarefaction or Ebullition; besides, as there are no productive Causes of such an Ebullition in the Heart, and as its Effects would be so highly pernicious, 'tis reasonable there should be none. If you are pleased to assert a latent or insensible Ebullition in the Heart, we shall not contradict, since our Concern is only with sensible Phænomena, productive of sensible Effects.

⁴ As the latest Asserters of these hypothetical Commotions in the Blood, have been forced to own them latent or occult; so their Effects are equally imperceptible with the Causes, and have only their Existence in a prejudiced Imagination.

§. 178. Nor does the *Warmth*¹ of the Heart cause any Change in the Nature and Motion of the Blood, nor expel it from thence.

¹ Since the Heat of the Heart is no greater than that of the other Arteries (§. 169.) Heat cannot be the Cause which forces the Blood out of the Heart into the Arteries, according to the Theory of *Cartesius*.

§. 179. Nor is there any kind of Ferment in the Heart.

Of this Opinion was *Vieussens*, who lately revived the *Cartesian* Hypothesis, and added new Arguments to it. 'Tis scarce credible, how a Man in his Senses should imagine a Fire or Ferment to be contained in the Cavity of a tender Muscle, as

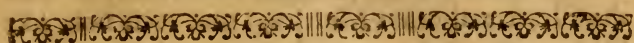
is

is the Heart. Who can believe that in the 7200th Part of an Hour is separated a liquid Ferment so very different from its Origin in the Blood itself, that in the same Instant of Time it can heat the Blood, and change its Nature ; or who can believe that such a Ferment should constantly reside in the Heart without being washed out, when no less than 600 medical Pounds of Blood pass thro' that Organ in the space of an Hour ? But this otherwise industrious Anatomist seems to have been led into the Mistake by an Experiment which he thought argued for the Hypothesis, *viz.* That upon injecting a coloured Liquor into the coronary Arteries, it passed through into the right Auricle and Ventricle of the Heart ; hence he rightly judged that the Blood of those Arteries passed very swiftly the same way, and by its Velocity acquired more Heat ; but then he was wrong in thinking that increased Heat sufficient to rarify and warm all the other venal Blood. We grant, that the Blood of the coronary Arteries does (by that increased Velocity and Attrition with which it passes thro' the Substance of the Heart, in its muscular Contraction) acquire a greater Degree of Heat, by which it may render the venal Blood with which it mixes somewhat more warm and fluid ; but then this Heat can never be sufficient to propel the Blood, and overcome the Resistance of all the Arteries, agreeable to the System of *Cartesius* ; nor yet can it produce that Difference which is observable betwixt the arterial and venal Blood.

§. 180. The Cause therefore which propels the Blood out of the Heart into the Arteries, and from the Veins into the Heart again, does not reside in the Blood.

The System of *Cartesius* and his Followers is,
 “ that the Blood being rarified by Heat, rushes
 “ out of the Heart, and dilates the Entrance of
 “ the Artery, in the same manner as when Milk
 “ boils up on the Fire, or as bottled Ale flies up
 “ in the Air as soon as you draw out the Cork,
 “ in which manner it will ascend even through a
 “ Tube, if you insert one in the Neck of the
 “ Bottle ; so that the Heart may be compared to
 “ the Bottle, and the Artery to the Tube, &c.”
 But as this Error has been long ago refuted, we
 shall only answer in brief, (1.) That the Blood in
 the Heart does neither ferment, effervesce, nor
 make any Ebullition. (2.) That it is not expell’d
 from the Heart in its Dilatation, but in its Con-
 traction or Systole. (3.) That if the Blood had
 any such Motion, it must be observable to the
 Eye, and afford a deal of Froth, neither of
 which can be demonstrated.

§. 181. But this Cause (§. 180.) must then
 be sought for in that which immediately re-
 ceives and retains the Blood, that is, in the
 Heart itself ; in which, in order to demon-
 strate it, we are first to make an acute Sur-
 vey of the Substance, Structure, Motion and
 Force of that Muscle.



Of the Structure and Action of the Heart.

§. 182. **T**HE Heart, being every way *at Liberty*¹ for Motion, in a *large*² membranous Receptacle, termed *Pericardium*³, (which is accurately closed on all Sides, and firmly attached to the Throat, Sternum, Spine, and *Diaphragm*⁴, either immediately, or by the Vessels and ligamentary Processes it sends forth) and being also moisten'd with a lubricating *lymphatic Liquor*⁵, expressed from the small Arteries in the Superficies of the Heart itself and its Auricles, is likewise sustained *pendulous*⁶ by its four great Blood-vessels, which its Pericardium very strictly embraces. Its Position is lengthways, in an oblique and almost *horizontal Posture*⁷, with its flat Side on the Diaphragm; to the tendinous or middle Part of which it is firmly connected by the Vena Cava and right venous Sinus below; and above, in the Thorax, it is connected within the Duplication of the *Mediastinum*⁸, and lodged betwixt the soft Lobes of the Lungs; by all which means it avoids too great a *Pressure*⁹ on any Side, and is most commodiously adapted to receive the Blood from, and propel it into all Parts of the Body¹⁰.

¹ This is one of the principal Differences betwixt the Heart and other Muscles, that it is not, like them, connected to any Bones, nor has any fix'd Point to act upon; for the very Weight which it moves, *i. e.* the Blood, is the Fulcrum whereon it acts, and which it discharges, by an unequal Pressure, where it meets the least Resistance, *i. e.* into the Arteries. Besides, if the Heart impinged against any hard Body in its perpetual Motion, as it has been sometimes observed to do, in those who have had their Thorax too much contracted, the Consequence must be a Train of Diseases, violent Palpitations, &c. which are thus avoided.

² So large that it will contain double the Bulk of the Heart, as you may be convinced by the Experiment of filling the Pericardium with as much Water as it will contain without Danger of bursting; and then, if that Water be discharged, and the Heart taken out, the Pericardium will hold twice as much as before; which Space was the more necessary in the Pericardium, that the Heart might move freely in it.

³ We know not of any Animal whose Heart is not defended with this Capsule; even Fish, who have this Organ placed in their Head, are furnished with a thick, fleshy, and sometimes cartilaginous Integument, which serves the Heart as a Pericardium. But a ligamentary or membranous Receptacle is not peculiar to the Heart alone; for every Muscle and Tendon has its Capsule, in which it moves, is lubricated, and is more or less at Liberty according to the Amplitude of its Motion.

⁴ In Brutes we find only the Apex of the Pericardium attach'd to the Diaphragm; but in the Ape or Monkey-kind its Connection a little more resembles that of the human Body, in which it lies flat,

§ 182. *Structure of the Heart.* 57

flat, with its Apex towards the right Side, and its Basis towards the left; its broadest Side being so intimately attached to the tendinous Part of the Diaphragm, as to be inseparable without Laceration, by which means it sustains that broad Muscle, with the several Viscera connected pendulous to it; so that the Diaphragm cannot by their Weight be drawn down too low in the Abdomen, in our erect Posture.

Great has been the Controversy among Anatomists, whether this Water or Lympha is always present in the Pericardium of the living Animal: Some affirm that it ought of Necessity to be there in the healthy Animal, and others assert that it never comes there but by Disease or Death. This Argument we shall decide without refuting either Opinion, as follows: It is certain from Anatomy, that a good deal of this Water is contained in the Pericardium of every Person who dies a lingering Death; and it is equally certain, that in those who are kill'd or die suddenly there is little or none to be found. To account for this, it must be observed that the Interstices in the Abdomen, Thorax, and all other Cavities of the living Animal, are replenished with moist Vapours, discharged by exhaling Arteries, the Existence of which in the Superficies of the Heart and its Auricles is proved by Injections: But this Vapour will be discharged more plentifully into the Cavity of the Pericardium, as the Membrane of the Heart is very thin, and as the Blood of its coronary Arteries is propell'd very swiftly and copiously in each Systole; with this Moisture the Heart will be lubricated, and that Friction prevented, which might inflame and occasion its Adhesion to the Pericardium. But these Vapours must be again received by the absorbing Veins, which probably convey them to the Lympha-

Lymphatics observed by *Nucke* in the Heart, or else they would be increased to a Dropsy, or become putrid and acrid by standing; they are therefore returned to the Blood again in the healthy Animal. But if these exhaling Arteries discharge more plentifully than the Veins absorb, as they must do when the Heart labours or palpitates by Disease or Death, these Vapours will be then turned to Water, and this Water will be accumulated to the Quantity in which we often find it. By this means also, when the absorbing Power of the Veins declines, in chronical Disorders, will be sometimes produced a Dropsy of the Pericardium; in which Case it has been found distended with several Pounds of Liquor. But when a Person is kill'd, or dies suddenly, the Heart does not palpitate long enough to express this Moisture in any Quantity; and then the Veins continue absorbing to the last, as they die in full Strength. To conclude, we may be sensible how necessary this Moisture is to lubricate and separate the Viscera, and especially the Heart; from the Histories given us by *Peyerus*, in which the Patients were troubled with the most violent Oppressions and Palpitations, because for want of this Moisture the Heart was found dry, and adhering to the Pericardium.

6 The great Blood-vessels of the Heart are extended near two Inches from its Basis before they unite with the Pericardium, and thus join that to the Heart. Nor is the Heart pendulous in us as in Brutes; for in the human Body its broadest Side lies flat upon the Diaphragm, which is sustained by the Pericardium and Mediastinum, and immediately subsides if you separate them.

7 This is one of the principal Circumstances in which human Bodies differ from those of Brutes; for in these last the Heart is placed according to the

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the Length of the Thorax, with its Basis next the Throat, and its Apex towards the Diaphragm, to which its Pericardium is slightly attached : But in human Bodies the Heart is placed nearly in a transverse or horizontal Posture, with its Basis in the right Side of the Thorax, and its Apex in the left, while its broadest and flat Side, from the Basis to the Apex, lies inclined and supported on the Diaphragm. This is the true Position of the Heart in the human Body, notwithstanding the Figures in most of our modern Anatomists are erroneous in this respect, being taken either from one another, or from Brutes ; but the Figures of *Vesalius*, *Eustachius*, and *Ruyfch*, shew the Heart in its natural Posture. From what has been here said we may resolve the Question, why over-eating causes a Palpitation of the Heart : For since the Heart is only separated from the Stomach by the Diaphragm, when the Stomach is over distended, it will force up the Diaphragm, and press upon the Heart, Hence also you may see how the Heart comes to be pressed up so high in the Thorax of those who die of a Dropfy in the Abdomen, and why it is forced so far down in the Abdomen of those who die of a Dropfy in the Thorax ; because the Diaphragm, to which the Heart is connected by its Pericardium, is forced either way by the contained Water.

⁸ This Partition is formed above the Union of the two Sacculi, which constitute the Pleura in each Side of the Thorax : But as those Sacculi of the Pleura descend, they recede from each other, and intercept the Pericardium.

⁹ The abdominal Viscera require a constant Pressure and Agitation from the Muscles ; they have therefore no other Defence ; the Brain being without any Motion, is therefore lodged in a Case of
mere

mere Bone: But the Heart and Lungs require to have their free and ample Motion, and to be defended at the same time; they are therefore seated in a Case of Bones that continually move, but keep off the Pressure of the ambient Muscles. The soft Lungs indeed press upon the Heart, when they are quite distended with Air, but without any Injury to it.

¹⁰ If any one shou'd ask why the Heart is not placed in the Center of Gravity in the human Body, that so it might more equally distribute the Blood to all Parts; it may be answer'd, (1.) That it is required to be near the Brain, that it might the more readily supply Blood to that Organ by the Carotids for all its Offices; agreeable to which, we observe in Man, the Elephant, and the other more sagacious Animals, that the Neck is but short. (2.) It is placed nearer the Arms than the Legs, as the first require greater Supplies to perform their various Actions in Life, which are much more noble, numerous and frequent than those of the lower Limbs. (3.) It could not be placed in the Abdomen, because of the Pressure there; nor could it be seated any where distant from the Lungs, as their Commerce in moving the Blood is immediate and inseparable; for which reason it lies in the Head of Fish, because their Lungs are there.

§. 183. The two coronary Arteries of the Heart arise on opposite Sides from the Aorta, a little *above* its semilunar Valves; and proceeding in *opposite* Courses, they unite and form one Canal; which surrounding the whole Basis of the Heart, sends off numerous Arteries, which variously communicate with each other by Anastomoses, and are spent
in

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in an infinite Number of *very minute*¹ Arteries, the smallest Series of which prevade the whole Superfices of the Heart both external and internal, and pour out a Liquor in the Form of Dew; so that the whole Substance of the Heart seems in outward Appearance to be made up of Arteries and Veins, ramified in the same Manner, with a Quantity of *Fat*² lodged betwixt them externally. 'Tis remarkable, that these Arteries of the Heart are in their *Diaſtole*³ at the Time when those of all the other Parts of the Body are in their *Syſtole*. The small Veins of the Heart convey their Blood partly into the *coronary Branches*⁴, which passing towards the right Auricle, have their *chief Opening*⁵ betwixt that and the right Ventricle, into which last they also open by several *venal Orifices*⁶, as well as into the Auricle: Of these Veins it is observable, that they are *emptied*⁷ while the other Veins of the Body are filled.

¹ About even with the Margin of the Valve which is farthest from the Heart.

² It was none of the least Discoveries of *Ruyſch*, when he observed the two coronary Arteries met together into one, from whence all the Branches are supplied to the Substance of the Heart, and by which means there is also an Equilibrium in the Distribution of the Blood.

³ The celebrated *Ruyſch* was persuaded, in one of his Preparations of the Heart, that the ceraceous Injection had passed or transfused like Down, thro' these small Arteries; from whence he concluded, that the Blood passed thro' them in the same Manner

Manner in the healthy Animal. But when I examined his Preparation by the Help of a Microscope in the Rays of the Sun, I observed that little Globules of the Injection had been forced thro' the smallest Arteries and escaped into the cellular Substance, which invests the muscular Fibres of the Heart. These smallest sanguiferous Arteries terminate either in Veins, or in lymphatic exhaling Arteries; which discharge the Water into the Pericardium; which Liquor is found of a reddish Colour in Animals that are opened after violent Exercise, as in Hares, Stags, Horses, &c. from the violent Action of the Heart and sanguiferous Arteries forcing some of the red Globules thro' the ferous or exhaling Arteries; whence people often make Bloody Urine after hard riding or violent Exercise, from the same Cause. Sometimes these small exhaling Arteries are so far dilated as to transmit mere Blood itself, so that after violent Exercise bloody Sweats and Urine have been observed.

⁴ A Quantity of Fat is constantly found intermixed with the coronary Blood-vessels about the Basis of the Heart; which sometimes abounds so much in Oxen and Swine, which have been fed in the Stall or fatten'd in the Sty, that the Blood-vessels of the Heart are compressed by the redundant Fat; whence too, those People who have the Blood-vessels of their Heart in this Manner overloaded with Fat, are of a sluggish Habit, and of dull Intellectuals: So that from hence we may understand the Scripture Phrase (*Acts xxviii. 27.*) *He hath fatten'd their Hearts, lest they should understand.*

⁵ The Principal of these opens towards the left Side of the right venous Sinus, and is furnished with a Valve at its Orifice, observed by *Eustachius*.

But

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⁶ But some open into the Vena Cava itself, just before it enters the Heart; but so that all the Blood from the Substance of the Heart arrives into its right Ventricle, and must pass thro' the Lungs before it can enter the left Ventricle.

⁷ Some of them larger than the rest, and described by *Ruyfch*; others of them very small, and opening into the little Sinus's in the right Ventricle, into which they transmit Water, Spirit of Wine, and even Wax itself, after Injection. These have been formerly observed by *Thebesius*; and *Vieussens* has made them the Seat of his imaginary Ferment of the Heart. All these small Veins seem to arise immediately from the Extremities of the Arteries, without having any Bibulous Veins: And there are few or none of them that we can observe to open into the left Sinus or Auricle.

⁸ This is a Circumstance that ought to be particularly remembered; that when the Heart propels its Blood into the Aorta, it is then pale, constricted and bloodless; which is a manifest Argument, that at that Instant it does not receive any Blood into its Arteries; and therefore the Aorta will be fill'd when the coronary Arteries are emptied: But the Heart, the Instant after its Systole, becomes relaxed, and the Aorta at the same Time contracts itself, by which the Blood is equally forced every way, as well back to the Valves, as forward to the Branches; by which Means it will enter and fill the relaxed coronary Arteries. Hence it follows, that as the coronary Arteries are not filled by the Heart, but by the Aorta, they will be in their Diastole, when the Aorta and all its other Branches are in their Systole; and in their Systole, when all the other Arteries of the Body are in their Diastole; which makes

makes the first Cause of the perpetual Motion of the Heart. But the next Instant after the Systole of the Aorta, the Heart again contracts forcibly, and, like other Muscles, expells the Blood in its Arteries ; so that by the same Action of the Heart the coronary Arteries will be emptied, while the Aorta is fill'd.

⁹ But as for the coronary Veins, they will emit their Blood either into the right Auricle or Ventricle into which they open, when either of them are relax'd.

§. 184. Besides the foremention'd Vessels (§. 183.) the Heart is also composed of muscular Fibres, which arise from four circular *Tendons* ¹, encompassing the four Apertures of its Ventricles ; in which Tendons most of the Fibres are also again inserted. From these Tendons arise, (1.) a small Number of slender Fibres, which are placed in almost a strait Course from the Basis to the Apex, on the Outside of the right Ventricle, serving to strengthen and assist the Contraction of the subjacent muscular Flesh of the same Ventricle in its Expulsion of the Blood. (2.) Under the preceding Fibres of the right Ventricle, *arise others* ² from the left Side of the Heart, which ascending obliquely towards the right Side, take a Spiral Course, and terminate in its Basis. (3.) Under the last Fibres there are again others, which ascend from the right Side of the Heart round its left, and encompassing both Ventricles, they rise up and terminate at the Basis of the left Ventricle ; so that

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that they intersect the Course of the last Fibres, or run in a contrary Spiral. The two last mention'd Series of Fibres (2 and 3.) are in common to both Ventricles, which they equally invest; and by their contracting in opposite Directions, they strongly and equally constrict the Heart on all Sides at one and the same Time, pressing both the Ventricles against their internal Septum, and drawing up the Apex towards the Basis of the Heart in the same Action. These Series of Fibres (2 and 3.) are again assisted in their Operation by (4.) another, which pass in an oblique Curve round the former, to which they are *connected*³, serving to bind them together, and retain them in their Places. But besides these, the left Ventricle has also two other thick Series of *Fibres*⁴ peculiar to itself; the Outermost of which, lying under the former, (2, 3, and 4.) ascend spirally all round the left Ventricle, towards the right; and forming Part of the Septum, they terminate in the Basis of the left Ventricle, whose Cavity they entirely surround, and are also confined or secured by other Fibres of their own, like those at (4.). Finally, (5.) under the preceding Fibres is spread the very last Series, which descending in an oblique spiral Course from the Basis of the left Ventricle, towards the right Side of the Heart, compose the internal Substance of the left Ventricle; and after completing the middle Septum of the Heart, the Fibres are spent in Curves of different Lengths, and appear variously con-

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torted

torted. *Add to these*⁵, that the fleshy *Columns*⁶, and the small Evacuations in the Sides of the left Ventricle, do fitly dispose it for a very strong and close Contraction, as well by its own proper Fibres, as by those in common to both Ventricles : While the other Threads and smaller Columns, formed in either of the Ventricles, serve to open the Valves when the Heart is dilating, and to keep them shut while it is contracting.

¹ The Margin of the arterial Aperture in each Ventricle is made up of compact Fibres, formed into a white callous and perfectly tendinous Substance. But the circular Tendons of the venal Orifices, tho' pretty firm, are not so callous as the former ; but are more fleshy, and ten times weaker. The right venal Orifice is composed from three Orders of Fibres, (1.) from those of the Heart, (2.) the Fibres of the lower Basis of the right venous Sinus, (3.) from the Fibres of the right Side of the Auricle. But the elliptic Tendon of the left venal Aperture is connected two thirds to the left Sinus, and one third Part to the left Auricle. From the Tendons now mention'd arise all the muscular Fibres in the Heart. The left venal Tendon is stronger than the right, and the left arterial Tendon stronger than any of them. These Tendons sometimes ossify in very old People, and in some Animals.

² These with the preceding arise from the Tendon of the pulmonary Artery, and are inserted into that of the Aorta ; that is, from the whole Circumference of the Back of the right Ventricle arise Fibres, which descending to the Apex of the Heart, invest both its Ventricles superficially,
without

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without touching its Septum ; and then ascending obliquely, they make the third Series of Fibres.

³ For none of the Series of Fibres hitherto described are free from each other, but closely connected and bound together by Fibres, partly muscular and partly tendinous ; which Connection is the more firm, as the muscular Fibres of the Heart are stronger.

⁴ These arise from the Tendon of the Aorta, and are inserted into it again ; they descend obliquely under the former Strata to the Apex of the Heart, where they are contorted into a strong fleshy Turbin ; from whence ascending spirally, they at length terminate in the Orifices of the left Ventricle, and compose the last Series. These two Series (4 and 5.) belong only to the left Ventricle, and compose its Septum. If we cou'd take them out from each other, we shou'd have two distinct Bags, having each their proper Cavity. The Mechanism of all these Fibres were first discover'd and represented by *Lower*, whose Treatise on the Heart I have gone thro' ten times, and always with new Pleasure.

⁵ Suppose a Man to have but one Ventricle in the Heart, *viz.* the left, and let that be composed of two Series of muscular Fibres running in a spiral Course, but contrary to each other, from the Basis of the Aorta to the Apex of the Heart, and from the Apex to the Basis again, in an opposite Course. Suppose also that it has but one Vein and one Artery ; this Man would be in the Condition of Frogs and Fish. If now another shorter and broader Ventricle be added, formed by the right Side of the preceding one behind, and by its own Flesh before and towards the right Side ; and let it consist of two Series of spiral Fibres running in contrary Directions, and retained by straiter ones

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externally; the spiral ones being also continued round the left Ventricle; you will then have that Ventricle composed of four Series of Fibres, and the right Ventricle composed only of two Orders, retained by a few slender straiter Fibres. Thus you will have a factitious Machine or Heart, having its left Ventricle longer and narrower than the right. Nor ought you to imagine what I have been saying to be either false or impracticable, since it is the very Course taken by Nature, as *Malpighi* observes in the Chick, in which, at first, appears only a crooked Tube instead of a Heart, which by degrees grows into a Heart, and two Auricles, at a Distance from each other; at length the two Auricles conjoin, as the two Ventricles did on the fifth Day of Incubation.

6 If the Heart was smooth internally, or if many of the muscular Fibres of the Ventricles did not strike out and terminate in muscular Papillæ, its Ventricles could never entirely empty themselves: So that we may reckon these the eighth and last Series of Fibres, and which are not inserted into any of the former Tendons.

§. 185. These Fibres (§. 184.) *arise* ¹ from the Branches of the eighth Pair of Nerves, which enter the Heart in a great Number betwixt the *Aorta* ² and pulmonary Artery; from whence they are dispersed into the Auricles and Ventricles, and constitute their muscular Fabric, especially in the capacious Ventricles, which are of equal Dimensions, and thus adapted to perpetual Contractions by the constant and powerful Action of their own Fibres without impairing their Structure.

As

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¹ As the muscular Fibres of the Heart are continued from the nervous, they therefore contract towards their Origin ; nor ought any body to think they are continued from the Nerves because they look red, for that proceeds from the Blood in the small Vessels spent on them, which being washed out, they look pale.

² This Course of the Nerves is admirably well described by *Lower* ; and it is principally this Course of them, betwixt the Aorta and pulmonary Artery, (with what we said of the coronary Arteries at §. 183. *ult.*) by which we shall explain how the Heart by its Contraction becomes the Cause of its own Relaxation, and how by its Relaxation the Cause of its Contraction is again renew'd. For it must be observed, that a Muscle becomes paralytic when it is deprived of its arterial Blood and nervous Juice, as we shall shew the Heart is by its Contraction. 'Tis certain that when the Heart contracts, it dilates the pulmonary Artery and Aorta, which will compress the Nerves passing into the Heart betwixt them ; and the same Contraction of the Heart will also force the Blood out of its coronary Arteries : Thus therefore the Heart's own Contraction will cause it to become relax'd or paralytic. But the Heart is no sooner relax'd than its Substance becomes soft, and the two great Arteries contract themselves into a less Diameter, forming a sufficient intermediate Space to free the intervening cardiac Nerves from Pressure ; whence will be present the first Cause necessary to the Motion of a Muscle (§. 402. N°. 8.) ; and at the same time the Aorta by its Contraction will force its Blood that lies next the Heart, into the relaxed coronary Arteries ; whence the second Cause necessary to move the Heart (§. 401.) ; at the very same Time too the Ventracles will be fill'd

with venal Blood by the Contraction of the Auricles, and hence the third or accessory Cause of the Heart's Motion, (§. 159. N°. 8.) Lastly, it appears that the Nerves of the Heart arise from the Cerebellum; for if the Cerebrum be injur'd, the Heart does not contract at all weaker than before; but if the Cerebellum be wounded, it suddenly stops. But as the Cerebellum has no Communication with the Body but by the Medulla oblongata, or by the Spinalis, the Heart has therefore Nerves from both of them; since from the Medulla oblongata arise the Intercoastal and eighth Pair; and from the spinal Medulla arise various Branches, which unite with the Intercoastal.

§. 186. It is therefore apparent from what we have advanced (§. 184, 185.) that the left Ventricle acts by an orbicular Contraction of its own Fibres, and the right Ventricle by a semi-orbicular Contraction, the left Ventricle being also assisted by the common exterior Fibres that surround both. This will appear evidently from dissecting the Heart and viewing its Structure.

The left Ventricle being a distinct Cone dilates itself every way, and contracts within its own Cavity, since the Septum belongs entirely to this; but the right Ventricle is an Addition only to the left, and contracts itself towards the Septum, which belongs to the left, as towards its fixed Point.

§. 187. The Heart then and its Auricles are *real Muscles*¹, and act with a muscular Force;
for

for its several Series of Fibres (§. 184.) being shortned in their Action, will contract the *Length*² of the Heart, and increase its Breadth, also at the same Time that they exactly diminish or contract the Capacity of both Ventricles, they will dilate the *tendingus Aperture*³ opening into the two great Arteries, close the Valves in the venal Orifices, and expell their contained Blood with a considerable Force by the same *Action*⁴, thro' the dilated Orifices into the Arteries. This is the Systole or *violent*⁵ Contraction of the Heart, in whose Structure there seems to be a latent and surprizing Propensity to contract and dilate alternately; even so as often to move in that Manner after the Animal is dead, and itself taken out of the Body, and even after it has been cut in Pieces.

¹ Its fixed Point is in the Tendons of the arterial and venal Apertures in the Basis of the Heart, its moveable Point is the Apex, and the Weight is the Blood, against which the Apex and Sides act or press, as against a solid Body, which the Blood at that Time resembles in its Resistance.

² They incurvate and draw the Apex of the Heart towards its Basis.

³ Their semilunar Valves are firmly inserted into the Coats of the Arteries themselves, next the Heart; but their Margins lie loose and fluctuating from the Sides of the Artery towards its Axis: So that when the Blood comes from the Heart, it will press these Valves close to the Sides of their Artery, whence they arise; and when the same Blood returns again towards the Heart by the Con-

traction of the Aorta, it will distend or fill out these Valves and close them together. But while the Fibres of the Heart, extended from the arterial Orifices to its Apex, are contracting and drawing the Apex towards the Basis, the Tendons in the arterial Orifices of the last will be in some Degree opened. But if the arterial Trunks are too elastic or resisting to the Ventricles of the Heart, these last will be considerably dilated by the Blood which they are incapable of expelling: Hence arise Aneurysms of the Heart, many of which are described by *Lancisi* in his Treatise on that Subject.

4 This Action is performed very swiftly, since in the Space of a Second of Time, or the sixtieth Part of a Minute, the Ventricles are both dilated and again contracted. But we shall not be much surpris'd at this Velocity of the Blood, and Motion of the Heart, which seem'd incredible to *Riolan*, if we consider the great and inconceivable Velocity with which the Muscles of Vocification act when we sing or speak. For by these we readily pronounce a Chain of ten Letters in the Space of a Second, and each of those Letters are accented by distinct and successive Actions of the several Muscles employed.

5 This being properly the Action of the Heart, arises from the Impulse of the nervous Juice into its Fibres, by which they are dilated and shortned; and from this Defect we always find the Heart in its Diastole, in dead Subjects.

§. 188. It is also evident that the Blood is thus *forced out of the Heart*, and propelled by its muscular Contraction, from its violent starting out of a Wound made in the pulmonary

nary Artery or Aorta near the Heart; as also from the violent Expulsion of the Blood out of a Wound in the Ventricles of the Heart, made by turning the Cone upward, cutting off its Apex transversly; and by the Pressure against one's Finger inserted into the Wound, together with the Turgescence, Hardness, Tension and Paleness of the Fibres; which also demonstrate the Contraction to follow, and not to precede the Repletion of its Ventricles, which are by that Contraction empty'd the Instant following.

1 The Heart in its Systole contracts the Cavity of its Ventricles, which Contraction must therefore force the Blood out of those Cavities into the Arteries; but in doing this, the Heart removes not only the Weight of the Blood in its Ventricles, but also the Resistance of the whole Mass of Blood in the Body; all which must be urged forward to make room for receiving that which comes next from the Heart. This Resistance of the Blood is of the same Nature with that in all solid Bodies, and therefore the Heart may be considered as contracting itself about a Solid, whose Resistance it overcomes by a superior Force; which expelling the Blood, thereby dilates the arterial Orifices as with a Wedge, while at the same Time those Orifices are also dilated in Part by the Contraction of the muscular Fibres of the Heart inserted into them.

2 'Tis computed that the Heart in its Diastole receives, in its Ventricles and coronary Blood-vessels together, about five Ounces of Blood; all which is by its Systole forced into the Arteries; and

and must therefore make a great Difference betwixt the State of it in the Systole and Diastole.

§. 189. If the Nerves of the *eighth Pair* ¹ be compressed by Ligature, or cut asunder in the Neck, the Motion of the Heart weakens, soon after palpitates with great Anguish to the Animal, and at length ceases, and therefore from these Nerves proceed the Origin and Continuation of the Heart's Contraction; which yet requires, like all other Muscles, Supplies of Blood by its coronary Arteries, and into the Cavities of its Auricles and Ventricles ².

¹ This is a remarkable Experiment of *Lower*, who observes that Dogs, who have the Nerves of the eighth Pair compressed by Ligature, do not survive above a Day or two. They do not expire sooner, because there are some smaller Nerves sent to the Heart from the Intercostals, which can hardly be any way compressed. But if, after opening the Cranium, you compress the Origin of those Nerves, *viz.* the Cerebellum or Medulla oblongata, then the Motion of the Heart is immediately suppressed, because you totally intercept the Passage of the nervous Fluid or Spirits to it. This last Experiment has been made by *M. Duverney*, who, after tying the Medulla oblongata, observed the Heart to stop from its Contractions; but upon relaxing the Ligature, it again recover'd its Motion.

² But besides those Causes there seems to be others not yet known; since the Heart has been seen to leap out of a Vessel of Water by its Contraction, after it has been cut from its Nerves and Blood-vessels, and taken out of the Body. The
Heart

Heart of an Eel beats about an hundred Times after it is taken out, and when it stops, it will again be put into Motion barely by the Warmth of the Hand. But even when it has done moving in the Hand, it may be again put into Contraction by pricking with a Needle: Also the Heart of a Dog, being quickly taken out of the Body and thrown into a Vessel of Water, will continue its Systole and Diaſtole for a conſiderable Time.

§. 190. The Blood being thus almost entirely expelled out of the Ventracles and Veſſels of the Heart by its Contraction (§. 187, 188.) its muscular Fibres then grow flaccid, from the Compreſſion of their Nerves by the Dilatation of the large Arteries; and the coronary Arteries being at the ſame time empty'd, the Ventracles become longer and narrower, the Diſtance betwixt the Baſis and Apex is thus increaſed, and the Contraction or Preſſure of the Sides internally is quite removed; ſo that the mitral and tricuſpid Valves being drawn towards the Apex of the Heart, in its Elongation, by their annex'd muscular Columnæ, the Ventracles will then be fill'd by the Contraction of the Auricles and venous Sinus's, which makes the natural or unactive State of the Heart, termed *Diaſtole* ¹.

¹ Every Muſcle at reſt is ſoft and flaccid, but when contracted they are in a State of Violence or Action, cauſed by the Influx of Juice by the Nerves and of Blood by the Arteries.

§. 191. But that the Ventricles of the Heart are in its Diastole filled with Blood, is demonstrated to us by opening one of the large Arteries near the Heart; and if the Heart of a living Animal be turned upward, and cut tranversly, the Ventricles will appear in their Diastole to receive and not discharge the Blood; which we are also assured of by Inspection in Animals open'd a little before Death, and from one's feeling no Pressure in the Diastole against their Finger, when inserted into the Ventricles by an Incision. It is therefore evident the Blood does not pass out of the Heart from any Rarefaction, but from its muscular Force.

§. 192. The *Chyle* * therefore being mix'd by a little at a Time with a large Quantity of venal Blood, is then more intimately mixed, attenuated and shook together therewith by the muscular Action of the Heart, and the Fabric of its muscular Columnæ in the right Ventricle, from whence they are propelled together into the pulmonary Artery.

* From what has been said of the Heart, its Action appears to be, (1.) To receive the venal Blood, shake it strongly together and attenuate it; since the Blood is swiftly divided into many small Portions by the muscular Columnæ. (2.) To make a more intimate Mixture of the Chyle with the Blood, and to render both of them more fluid, by joining the very highly attenuated Blood of the coronary Vessels, thro' which it passes swifter than any other Vessels. But this Mixture of Blood
from

from the coronary Vessels is made only in the right Auricle and Ventricle, since that in the left, which has passed swiftly thro' the Lungs, does not stand in need thereof, to prevent its Mass from congealing, to which the Blood has naturally a strong Inclination ; and from whence it easily runs into polypous Concretions for want of sufficient Motion in the dying Animal. (3.) The last Action of the Heart is the Propulsion of the Blood into the Arteries, and maintaining its Fluidity. In this Action the Heart must exert a very considerable Force, since it overcomes the Resistance of all the Arteries in the Body ; the same Force will also appear to be great from the muscular Fabric of the Heart, if compared with that of the small Intestines ; which last, tho' their Action is so very considerable, have not their muscular Coat above the thirtieth Part so thick as the Ventricles of the Heart.

² The right Ventricle propells about two Ounces of Blood into the Lungs, in every Second of Time ; and the left Ventricle distributes, at the same Time, about the same Quantity of Blood by the Aorta thro' all Parts of the Body. Some indeed imagine the Quantity of Blood expell'd in each Systole of the Heart, to be much less than that here mentioned ; but this Computation is most agreeable with the Capacity of the Ventricles in the human Heart, and with the Observations made on the Quantity of Blood expell'd in each Systole of the Heart in Dogs open'd alive. A less Quantity would not dilate all the numerous Arteries at each Systole of the Heart, in the manner we observe ; and even a large Ox expires in eight Minutes, by dividing an Artery which lets out thirty Pounds of Blood, all drove out by the Contractions of the Heart : Whereas if the same Artery be open'd

each other upon the former ; to which add the Thyroarytænoide and *Hyothyroide* ⁶ Muscles compressing the upper Part of the Larynx in its Elevation. The Rima is again dilated by the Crycoarytænoidei postici and laterales, as also by the Sternothyroides, which pulling down the Larynx from the Epiglottis, gives a free Passage for the Air to enter and return.

¹ That the Larynx has no Share in Respiration, but only serves to shut the Trachea and form the Voice, we are assured by Experiment in a Dog, whose Larynx being divided from the Trachea, he continues nevertheless to breathe freely through the Wound, only without howling or making any Noise.

² The Rima is seated almost horizontally, and intercepted by the Conjunction of Cartilages, Glands, and two Ligaments, which are best described by *Morgagni*. This Aperture is long, and not round, that it might be more easily closed, and also prevent any Bodies from slipping into the Trachea which wou'd excite the most dangerous Symptoms, and even Death, as I observed to you in (§. 70. *ult.*) of a Gentleman that was strangled at a Feast by a Morfel slipping into the Windpipe : But the Rima being long and narrow, is the better fitted to keep out the Dust, Insects, and Particles of the Aliment.

³ These Cartilages are furnish'd with Glands, which when deprived of their Mucus occasion a Hoarseness, and when tumified, a Quinsy : Their Mucus serving to lubricate the interior Surface of the Larynx. But round the Larynx above, or on its Outside at the Root of the Tongue, there is a great deal of Mucus supplied from the glandular
Expansion

Expansion of *Vaterus*, and the *Cryptæ* or simple Glands of the Epiglottis. Besides these, the internal and smooth Membrane investing the Cavity of the Larynx is also full of very small Glands, which discharge a lubricating Juice; which being obstructed, occasions a Hoarseness and Difficulty of Breathing.

* There are properly but four Cartilages of the Larynx, since the Epiglottis does not make up any Side of the vociferous Tube, but serves as a Cover to prevent any Mucus, Drink or Particles of the Aliment from falling therein. It was necessary for the Epiglottis to be an elastic Cartilage, that its own Weight might not depress it, and yet that it might yield to the Pressure of Liquors, &c. to close the Larynx, and prevent their escaping into the Windpipe to the Hazard of Life. For no Person can survive without quick Supplies of fresh Air this way; and if any Particle of the Aliment falls in, or even a Drop of Liquor, it is immediately expell'd by a strong convulsive Cough, or else a Suffocation will follow; which may yet be prevented by instantly performing the Operation *Tracheotomy*, that is, dividing the Trachea just under the Larynx: For that Wounds of this Part are curable, and not mortal, may be concluded from the one Instance (among many others) of a Man who recover'd after his Throat had been cut by Robbers, in *Philos. Trans.* N^o. 258. And tho' these Cartilages are very thin and flexible, yet they are connected to each other by very strong Ligaments.

⁵ This Ligament is composed by a Reduplication of the external Integument of the Tongue; and its Place is supplied in Oxen, Sheep, and other Animals, by distinct Muscles serving to elevate the Epiglottis.

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6 The Muscles which approximate the Sides of the Glottis when we speak or sing in an acute Strain, and which close the Glottis when we hold in our Breath, must exert a very considerable Force ; since they resist and overcome the Force of the Air confined in the Lungs, and endeavouring to expand itself, or escape ; for we can so strongly contract the Cartilages of the Larynx by their Muscles, that tho' the Nose and Mouth be open, yet the Air can neither pass into nor out of the Lungs ; by which means the Slaves of *Angola* frequently suffocate or strangle themselves voluntarily, when they think themselves hardly used by their Masters ; and in this Case, no Remedy will so well succeed as Stripes and Blows to make them cry out or breathe ; and if this fails, they presently expire. But those Muscles which dilate the Glottis are not near so strong as the former, which contract it ; since we do not use them to open, but only to enlarge the Rima of the Glottis, when we express grave Tones ; for that this Part naturally remains open of itself, is apparent in our Sleep, at which Time we breathe freely tho' the Muscles are relaxed.

These Muscles draw the whole Larynx towards the Root of the Tongue, and close the Rima of the Glottis.

§. 195. In the next Place, the *Aspera Arteria* or Windpipe, consisting of *semicircular*¹ cartilaginous Segments, with their back Parts membranous, and connected together by strong *muscular Ligaments*², gives a free Ingress and Egress to the Air from the Glottis through its Capacity, which is always open, and lined with a smooth lubricated *Membrane*³ ; so that it will expand circularly by the Air, give way

to the Gula in Deglutition, follow the Posture or Bending of the Neck, and become either elongated or contracted as there may be Occasion. But the whole Membrane, which makes up the Back of the Trachea, where the circular Cartilages are deficient, is beset with small Glands, which separate an *unctuous* ⁴ Humour, discharged by their Ducts, perforating the tendinous Coat, into the Cavity of the Trachea, whose Surface is hereby lubricated and defended.

¹ These Cartilages are much more than semicircular in Brutes, forming more compleat Circles in them than in the human Species; because the first have their Necks pendulous, with the Windpipe under the Gula. But it was necessary for the annular Cartilages of the Trachea to be more imperfect or membranous in the human Species, (1.) that the Oesophagus might not be compressed or resisted in Deglutition by the harder Cartilages; and, (2.) that the Trachea might the more readily contract, elongage, and conform to the various Motions of our Necks, and dilate itself laterally when we utter grave Tones.

² The intermediate Spaces betwixt the Cartilages of the Trachea, which make about a fourth or fifth Part of it, are filled or compleated with two Series of muscular Fibres. The posterior or internal muscular Fibres draw the Cartilages into Contact with each other, to utter acute Tones; and when they are relax'd, the Cartilages separate and recover their former Places by their own Elasticity. But the exterior or longitudinal Series of muscular Fibres arise each from the upper Margin of the lower Cartilage, and are inserted into the inferior
Edge

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Edge of the upper Cartilage ; and by drawing the Cartilages together, they shorten the Trachea, and make it yield a grave Tone. These Muscles are therefore under the Influence of the Will, and I usually entitle them *Mesochondriaci*, from their Situation betwixt the Cartilages.

3 So extremely sensible, that Nature has placed it as a Guard to watch at the Door of our Breath and Life, that we might not be suffocated by any Particles falling into the Trachea : For all Bodies irritate it but the pure Air ; even a Drop of clear Water excites a convulsive and troublesome Cough, which does not cease till the Liquor is ejected by the Impetus of the Air, drove out by the Contractions of the Diaphragm ; which Precaution was necessary to prevent our Lungs from being injured unknown to us.

4 This Liniment, which lubricates the Membranes, and prevents their drying and shriveling with the Air, is secern'd into *Cryptæ* by simple Glands, seated in the membranous or back Part of the Trachea, where the Cartilages are wanting, while the continual Motion of the Trachea promotes the Secretion. It is sometimes spit up in a Morning under the Name of Phlegm, after it has been accumulated and inspissated by the Air in the Night : And when it is deficient, the Air itself proves so irritating to the Membranes, as to excite a troublesome Cough, often attended with a spitting of Blood ; but when totally wanting, or dry'd up, the Voice becomes squeaking, as if it came thro' a metal Pipe, which is judged a mortal Sign by *Hippocrates*. It is retained in the *Cryptæ*, or small Vessels, to thicken, and be ready for Expression when it shall be most wanted.

§. 196. The Trachea dividing itself into *two*¹ about the fourth Vertebra of the Thorax, is still composed of Cartilages that are imperfect Rings², compleated on their back Part with the aforefaid glandular Membrane; but it immediately afterwards divides into an infinite Number of Branches on each Side, having each the same Structure as at §. 195. only the cartilaginous Segments are more and more compleatly annular; and the *Lacunæ* discharging the oily or mucous Liniment, continue to open internally betwixt their tendinous or connecting Fibres: These Branches, or Bronchia, go off in acute Angles, and lie incumbent on each other; becoming gradually smaller and thinner, till at their Extremities the cartilaginous Texture is changed into a thin Membrane formed into many pliable Cells or Sacculi, all opening into the Extremity of the Branch from whence they arise; and these *Cells*³, being formed into *Vesiculæ* and Bundles, compose Lobes, of which there are five in the Lungs, two in the left, and three in the right Side of the Thorax; which again make up the whole Body of the Lungs, so far as it is an Air-vessel.

¹ Of which, that on the right Side divides into three Branches, behind the Curvature of the Aorta, and composes so many Lobes of the Lungs; while that on the left Side only divides into Branches, and composes two Lobes.

² The cartilaginous Segments of the Trachea do not become compleat Rings immediately upon its Division into the Bronchia, as many have imagin'd; but their membranous Deficiency still continues, tho' less, as the Bronchia ramify farther, as hath been long ago justly observed by *Eustachius*. This is therefore an Argument that the Deficiency in the Cartilages was not made barely for the Sake of the Oesophagus.

³ This Structure of the Lungs was first beautifully demonstrated by *Malpighi* in a Frog; in which the Lungs appear composed of two Bladders, divided into many hexagonal Lobules, connected to each other, and their Surfaces spread with Blood-vessels. The same Structure obtains in the human Lungs, but more obscurely, because of the exceeding Smallness of the Cells. But those Cells are found composed of two Membranes, one a Continuation of the external Integument of the Bronchia, and the other of the internal Membrane of the same Bronchia; but betwixt the Membranes of the Cells we have no Appearance of any Cartilage as we have in the small Bronchia. From hence it follows, that as the Trachea and Bronchia are cartilaginous all the way from the Larynx to the Cells, and as the Resistance of the Cartilages gradually lessens towards the Cells, the Air by its Weight will have a free and speedy Course into the Cells, where it meets the least Resistance. The Lungs will therefore be distended most where they resist the least, and where the Columns of Air are longest.

§. 197. If then the Air be *admitted* thro' the Glottis into the Trachea and Bronchia, as it is an elastic and heavy Fluid, it will inflate

or distend those Tubes with their Branches and Cells ; all which will be hereby enlarged both in Length and Diameter ; at the same Time the Branches of the Trachea will *arise* ², and separate into larger Angles, their Lobes will be elevated or fill'd, and the Cells will be distended from their flat or compressed Figure into one more spherical or capacious ; and from hence, the Spaces betwixt the cartilaginous Segments, Branches or Bronchia, and Vesicles of the Lungs, will be increased, and come *less into Contact* ³, *in Proportion* ⁴ as the Lungs fill with Air ; the Quantity of which may be known by blowing into a Vessel furnished with a Barometer, or by the swelling of the Thorax in a Bath.

¹ The Air is not admitted into the Lungs but by the Dilatation of the Thorax ; for when that is contracted, the Air in its Cavity and in the Lungs is of the same Tenure with the Atmosphere ; so that an Equilibrium arises from the internal Air resisting the external, whose Pressure is equal to a Column of Mercury 28 Inches high, or 32 Feet of Water. But so soon as the Thorax is dilated, the Lungs follow the Enlargement of its Capacity ; and their included Air being thus rarified or extended into a larger Space, does no longer resist the external Air ; which therefore enters into the Lungs in such a Quantity, as will reduce the rarified or included Air to the same Density with the external. The first Effect therefore of the Air rushing into the Lungs will be (1.) the Extension of it longitudinally ; after which follows (2.) an Expansion of it laterally ; from both which arises
(3.) a

(3.) a Change in the angular Position of the Vessels, and the Increase of their intermediate Spaces; and lastly, (4.) a Dilatation of the Vesicles or Cells.

² The Bronchia do not all descend; for since the Trachea, from whence they arise, descends into the middle of the Lungs before it sends off the Bronchia, the uppermost of them may be properly said to ascend; and all of them distended with Air, are thereby elongated, enlarged laterally, and placed in larger or more obtuse Angles, assuming a Form that renders them the most capacious. It is also easily demonstrable, that a Trunk dividing into two Branches, will be the most capacious, when the Branches meet the Trunk at right Angles; for since Cylinders of the same Base are to each other as their Heights, an oblique Cylinder will not be more capacious than a straight one of the same Base that is shorter; and therefore an oblique Cylinder reduc'd to a straight one, without changing its Length, will be more capacious, because its Height increases, and it will be still more capacious if elongated. When the Thorax is contracted, the cartilaginous Rings of the Bronchia are drawn together by their Muscles, and by the same means the Sides of the Trachea are absterged, and the Mucus carried off by the Impetus of the Air in coughing.

³ The empty Cells lye with their flat Sides close to each other, but when distended spheroidically as Spheres touch in the fewest Points, the Blood-Vessels therefore will be most at Liberty, and Circulation through the Lungs freest in Inspiration. That all hollow Membranes do by an equable Distension of their Sides become spherical, is proved at large by *Bernouli, De Mot. Muscular, §. x* and that the Pressure or Distension of the Sides of

the pulmonary Cells is very great, may appear from the Force of the Air which acts on them.

4 The Lungs is the largest of all the Viscera; nor ought its Size to be judged of from the Bulk in which it appears in dead Subjects, since it is in them very much collapsed and shrunk, whereas when they are distended with the Air in the living Subject they fill the whole Thorax; so that deducting the Heart and pulmonary Blood-vessels, the rest of the Space in the Thorax will be almost wholly occupied by Air.

§. 198. Here also the pulmonary Artery being incurvated immediately at its Rise from the Heart, divides itself into an infinite Number of Branches, distributed along with the Ramifications of the Trachea, and possibly subdividing into all the lesser Series of Arteries, as sanguiferous, seriferous, lymphatic, &c. the smallest Ramifications of which are spread like a *Network*¹ upon the Surfaces of the pulmonary Vesicles, and also in like manner upon their Cells or intermediate Partitions, and after forming an Infinity of arterial Anastomoses with each other, they at last terminate in corresponding Veins.

¹ We observed that the ultimate Ramifications of the Bronchia end in the Vesicles of *Malpighi*; to which add, that the Arteries in their smallest Divisions compose a reticular Expansion, running round the small Bronchia without opening into their Cavity, but proceeding forwards superficially till they open into corresponding Veins, without any glandular Fabric intervening. But the last Distribution

bution of this vascular Plexus is betwixt the two Membranes investing the Trachea, and which compose the Vesicles on whose Superficies the reticular Plexus is expanded, and also round the Trunks of the Air-vessels or Bronchia. Another Disposition of the Vessels is betwixt the Bronchia, in their Intervals, and the last Expansion of them is within the Interstices of the Vesicles, betwixt which is interposed the common cellular Membrane, affording possibly some Oil, but very little and subtle; for the Lungs have the least Fat of any Viscus.

§. 199. The small pulmonary Veins having also their Distribution and Intertexture like those of the Arteries, (§. 198.) receive the Blood brought to them by these last, (after having suffer'd the Action of the Lungs, and lost little or nothing by *Secretions* ¹ in the way) and convey it into the larger Branches of the pulmonary Vein, which at last terminate in four Branches still larger, through which the Blood passes into the Sinus of the pulmonary Vein, and from thence into the left Auricle and Ventricle of the Heart.

¹ There are no Secretions made from the Blood of the pulmonary Artery; there is indeed a Secretion made by some conglobate Glands in the Lungs, and by the Cryptæ of the Trachea and its Branches; but then both these are supplied by the bronchial Artery of *Ruyfch.* Therefore all the Blood brought by the pulmonary Artery is again returned by the Vein of the same Name, in which the Blood instead of losing gains something from the bronchial Humours taken in by bibulous Orifices, per-
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vious to the Air, and even the Injection of *Rusch*, and seated in the pulmonary Cells. There is also some Lymph returned into it by the Lymphatics which are very numerous in the Lungs.

§ 200. From considering the fore-mentioned Structure of the Lungs (§. 194 to 200.) with the Action of the Air upon them (§. 197.) and the swift Course of the Blood and Chyle thro' them, we may understand what Effects or Changes are produced in those two Liquors by the Force of Respiration: Such as,

1. This mixt Humour being drove, by the Force of the adjacent right Ventricle of the Heart, into a crooked, conical, flexible, elastic and resisting Artery, its component Particles will be *compressed*¹, compacted or condensed, their Points of Contact and Figure will be continually changed, their Cohesions separated, their Sides ground against each other, and their Fluidity preserved; whence the Blood will be fitted to pass through into the pulmonary Veins in the same Quantity as it was drove by the Heart into the Lungs, which is therefore a Strainer to the whole Body; all which holds true, even of the Blood passing thro' the Lungs of a Fœtus in Utero.

2. The Motion of the Vesicles in the Lungs, distended by Inspiration, in which they successively touch or compress each other in *fewer Points*²; while the Cells at the same Time gradually change their Shape and enlarge their Dimensions; and the Motion of the Vesicles and Cells gradually contracting themselves

selves in *Expiration*³; and the *Elasticity*⁴ of the retained Air continually increasing by the Warmth after Inspiration and Expiration, do all of them occasion the Pressure made on the Vessels and Humours of the Lungs to be unequal and successive, changing every *Moment*⁵: Hereby then the Blood, Chyle, and their Humours will be reciprocally pressed, *agitated*⁶, *propell'd*⁷, ground together, *dissolv'd*⁸ and made fluid, so as to be fit to pass *all of them thro'*⁹ the small Vessels of the Lungs. The Lungs distended with Air by Inspiration look pale, the Arteries and Veins spread themselves, and give less Resistance to the Blood impell'd from the right Ventricle of the Heart, while by the same means the Course of the Blood into the Veins is expedited, and in them accelerated towards the left Ventricle; but when the Lungs are contracted or collapsed, as in violent Expiration, it is hardly possible to fill the pulmonary Artery by injecting any Liquor; whereas when the Air-vessels of the Lungs are inflated, the Blood-vessels do then easily admit of being fill'd.

3. The Chyle therefore which has been prepared in the Mouth, digested in the Stomach, elaborated in the Intestines, secreted in the Lacteals, attenuated at the mesentric Glands, and farther diluted and mix'd in the thoracic Duct, then blended with the venal Blood, afterwards more intimately mixed, dissolved, and *digested*¹⁰ or attenuated by the right Auricle and Ventricle of the Heart, is lastly impelled

pelled into the conical Branches of the pulmonary Artery, by whose Sides being resisted, and still urged on behind, it receives a violent Pressure, whereby its Particles take a *Configuration* ¹¹ suitable to compose all the solid and fluid Parts of the Body.

4. The Chyle and Blood are again very intimately *mixed* ¹² in the pulmonary Veins; where

5. They are also diluted by the Lympha, which first receives the Impression of the Lungs on its proper lymphatic Vessels, as the Blood did in its Vessels.

6. By these means they seem to put on a Form fit for *Nutrition* ¹³.

7. The *Fluidity* ¹⁴ and *Warmth* ¹⁵ of the whole Mass is this way maintained.

8. We have here a very intimate Commixture of *all the new and old Juices* ¹⁶, and their several Particles throughout the whole Body.

9. Lastly, From hence seems chiefly to arise that *red and florid Colour* ¹⁷ which is so essential to good Blood.

¹ The nutritious and healthy Parts of all our Juices, which are either of a micilaginous or globular Texture, and kept continually within the Course of the Circulation, are all of them compressible, and disposed to run into close Cohesion as well as into Contact with the Parts of each other. But we have already seen that the Arteries are elastic Canals, resisting the Force of Dilatation (§. 132.); and that when the dilating Force ceases

to act, they contract to their first Diameter : By this Resistance therefore, in the pulmonary Artery, the Blood will be repell'd towards the right Ventricle, from the conical Sides of the Artery, and again returned in the Syftole of the Artery towards the same Sides, by which means the Particles of that compound Fluid will impinge against many Parts of the same Vessel. But this Repulsion of the Blood from the Sides of the Artery is always proportionable to the dilating Force or Impulse given to that Liquor by the Heart ; so that by the Inequality of these Forces, and Contrariety of their Directions, the Particles will receive a vortical or whirling Motion about their own Axes, and about the Superficies of each other. By the same contrary Forces, the Heart impelling and the Artery repelling at the same time, the Particles will be also compressed ; and the more, as no Arteries have their Origin and Termination so near together as those of the Lungs ; to which add the Resistance at their Anastomoses from the Pressure of the Air in Inspiration. In consequence of these Causes, the fluid Parts will assume a spherical Figure ; for every pliant Body will become a Sphere from an equilateral Distention internally, or a like Compressure externally. But as the pressing Cause is here external, and as Spheres contain the most Matter of any Surface, the Particles will also become more dense and heavy by the same means : It therefore follows from hence, that the Parts of the Blood and Chyle assume their Sphericity, and augment their Density from this Power in all the Arteries, but in none so much as those of the Lungs ; because the same Quantity of Blood passes through them, in the same time, as the like Quantity is distributed all over the Body ; and therefore the Blood will pass with a greater Velocity,

city; in Proportion, thro' this Viscus, as it is less than the whole Body. Thus you have my Theory of Sanguification, or the Chyle made Blood, chiefly by the Lungs; in which Viscus the Globules also acquire that Density by which they exceed the specific Gravity of Ale, Water, and other Liquors, one twelfth Part; and which I take to be greater while they are compressed in the Vessels than when only pressed by the Air. This Compressure of the Blood in the Lungs, by which its Parts acquire their Density, is greatest in the Arteries when the Lungs are contracted in Expiration, when it cannot pass freely into the Veins, and is still urged into the Artery by the right Ventricles.

² If a Bunch of Bladders were empty of Air, and pressed close together, they would come wholly into Contact; and this being the Case in the Lungs of the Foetus, they sink, even in Salt-water; but if, by one common Duct, those Bladders are inflated, by assuming a spheroidical Shape, and departing from each other, they will touch in but few Points, and leave intermediate Spaces of angular Shapes; and it is in these Spaces, however small in the Foetus, that the pulmonary Blood-vessels are distributed. Hence one may perceive, that when the Vesicles are inflated, and their Pressure taken off from the pulmonary Arteries, these last will be then more filled or distended by the impelling Force of the right Ventricle; and the Veins being also more at Liberty, the Blood will enter them more copiously, and return more swiftly to the left Auricle; and thus it is that the Lungs, which, before Birth, transmitted only one third Part of the Blood from the right Ventricle, does, after Inflation, transmit the whole thro' its Vessels. That the Force with which the Lungs are inflated by
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the Atmosphere is very great, we know by its Pressure and Velocity with which it rushes into a Vacuum. Nor can we retain the Air long after Inspiration; for by dilating the Vesicles too much by its Expansion, the Blood-vessels will be compressed near as much as when the Vesicles are flaccid in Expiration.

³ In this State the Diaphragm returns upwards, the Ribs and their elastic Cartilages descend, and both contract the Capacity of the Thorax, whereby the Vesicles in the Substance of the Lungs are compressed, their Sides brought into Contact, and their included Air by that means expell'd. This will diminish the angular Spaces betwixt the Vesicles, compress the Blood-vessels there distributed, and prevent the Blood from passing freely thro' the small Branches of the pulmonary Artery; in which it will be therefore accumulated in Expiration, while the same Compressure that obstructed the Blood in the Artery will accelerate it in the Vein by propelling it from the smaller towards the larger Branches, and into the left Sinus. The Blood of the Vein then will be accelerated both in Expiration and Inspiration, and most retarded during the Interpause or Rest of the Lungs.

⁴ The Air presses on the Vesicles of the Lungs not only by its Weight, but also by its Elasticity or Spring, augmented by the Heat or Warmth of the Blood in this Viscus, by which it will be rarified and expanded successively, till it becomes as warm as the Blood itself. The Air will be therefore warmed by the Blood, and the Blood cooled by the Air, in the Lungs, in Proportion to the Temperature of either; insomuch that if the Blood moved as slow in the Lungs as in other Parts, it would be quite congealed there by a hard frosty Air.

⁵ So long as the Air expands the Vesicles of the Lungs, the Blood will have a free Course from the Artery into the Vein ; but in different Degrees : For from the first Entrance of the Air in Inspiration, the Vesicles and Bronchia will be dilated gradually, and then a little time will pass in the Height of the Dilatation ; after which, they again gradually collapse. Hence will arise a mutual Attrition betwixt the Blood and its Vessels, whereby the grosser Parts will be dissolved into lesser, the smaller compacted into larger, and the Asperities abraded from both. All this will be again promoted by the Fabric and Disposition of the Vascular Plexus, in which the small Vessels mutually concur, and then separate like the Marshes of a Net.

⁶ This Agitation arises from the Parts of the Blood being divided in the reticular Plexus of *Malpighi* ; and altogether the same Effect happens to the Blood in the Muscles when in Motion, upon whose Fibres the Blood-vessels are expanded reticularly as in the Lungs ; but as the Lungs also act with an additional Pressure from the Air, as well as by their Motion, the Blood will receive a greater Shock and Agitation in them than in the Muscles.

⁷ Nothing is so effectual for preventing and removing Obstructions in the Vessels, as an alternate Pressure of their Sides, while the Fluid is impell'd thro' them ; for thus the leathern Pipes of Fire-engines, when obstructed by the Mud or Clay of foul Water, are easily cleared by the Impulse of the Water, and moving or varying the Course and Direction of the Pipes. And from this Principle it is, that the Vessels of the Lungs are so seldom obstructed, tho' they receive all the crude Chyle, and Cold of the Air.

⁸ Dissolution is most effectually performed by communicating fresh Shocks or Impulsions to the first Motion receiv'd by the Parts of Bodies, join'd with an Attrition: For it is thus the most compact Metals are dissolved.

⁹ The light, spongy and multiform Particles of our Chyle wou'd not be capable of pervading the minutest Vessels of the Body, as they must do for Nutrition, if they were not first highly attenuated, smoothed and rounded by the Lungs; in which consists the chief Office of this Viscus, as subservient to Sanguification and Nutrition. For none of the Chyle is convey'd through the Arteries to any Part of the Body before it has first passed through, and been divided by the Lungs: But should the Chyle present itself to the smallest Arteries without this previous Attenuation of the Lungs, it would from the Structure and Minuteness of them be absolutely unpassable, and produce incorrigible Obstructions; as it never fails to do even in those who have bad Lungs, or breathe less frequently, as in the Sedentary, &c. It is therefore in the Lungs chiefly, that the Particles of the Chyle receive (1.) a great Attrition, by which they are broke, polished, and rounded; (2.) a Compressure, by which they are densified and formed into Spherules; (3.) a Lubricity and Aptitude for Motion, by being strained thro' the smallest Vessels of this Organ. For it is certain, that the Vessels appear no where more minute than in the Lungs; and those being contracted beyond their natural Diameters in the Expiration of this Viscus, if the Chyle can pass freely thro' these Obstacles or Resistances, there is no Danger of its meeting with greater in any of the other Parts before it returns again.

¹⁰ Before our alimentary Juices can be fit to nourish the several Parts of our Bodies, it is first re-

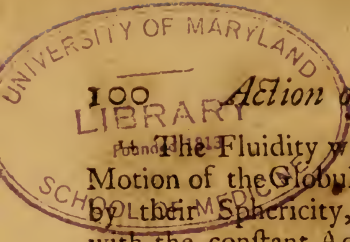
quired that they become in all respects like the White of an Egg, only more fluid ; for we find that barely from this Albumen, attenuated by Incubation, arise all the solid and fluid Parts of the Chick within the Space of twenty one Days. Now the serous or lymphatic Parts of our Blood are those which come nearest to the Nature of *Albumen Ovorum* ; for this Part, separated from the Cruor, has nearly the same sensible Qualities with the Albumen ; the same Softness, Glutinosity, and Disposition to harden in *Alcohol Vini*, and in boiling Water, also affords the same Principles by chemical Analysis. We also know from the Experiments of *Lower*, that the Chyle, which floated visibly in the Blood a few Hours after a Meal (§. 130.) does, in the Space of twenty-four Hours afterwards, intirely disappear, and the Serum of the Blood is increased in its stead. But this great Change is made chiefly by the Action of the Lungs ; for the Chyle is best disposed to turn into Serum in the time of Sleep (§. 597.) ; but then all the voluntary Muscles are at rest, and the Lungs still continue to labour,

“ We know that all our Juices appear globular, and that every Particle or Body pressed equally on every Side, and turned round on its Axis among others, will become spherical ; but this being the Case, in an eminent Degree, with the Particles of the Chyle in the Lungs, it is in them chiefly that their globular Figure will be acquired. What greatly confirms this Action of the Lungs, is the swift Motion of the Blood and Chyle, and large Contact betwixt them and the Arteries in this Part. For I am constantly confirmed in my Opinion of the sanguiferous Arteries dividing themselves into many lesser Orders, decreasing in Proportion to the Series of Globules, and that all those Series
of

of Vessels are dispersed in the Lungs; and therefore I judge that it is in the Lungs, that the Blood and Chyle are prepared and fitted to pass swiftly thro' all the Series of Vessels in the Body; especially as there are no Glands or secretory Organs in the Lungs to retard the Blood. The lymphatic Vessels observed in the Lungs do also demonstrate, that the Branches of the pulmonary Blood-vessels are not all of them sanguiferous, but that they divide into smaller, conveying Juices more subtle than the Blood.

¹² Three Things are required to a perfect Mixture in a compound Fluid, (1.) an Attenuation or Smallness of its Parts; (2.) an intestine Motion of its Particles in different Courses and Directions; (3.) a progressive Motion or Agitation of the whole Mass: All which Causes are administer'd to the Blood and Chyle in the Lungs; by whose Action it is that the Chyle, after it has circulated for some Time distinguishable from the Blood, becomes at length homogeneous with, or undiscernible from the Blood itself.

¹³ In order for Nutrition, it is necessary for a large Number of Globules to be prepared of different Sizes, that every Series of Vessels may be supplied with those that fit their Diameters. This then will be another Action of the Lungs, to divide many of the larger Spherules into lesser ones, whence the Fluidity will be increased, and polyposc Concretions prevented. And from the Sphericity and Rotation of the Particles, their Points of Contact will be continually changing, and varying their Directions. Hence all those Particles which easily assume a spherical Figure, may be consider'd as alimental; those which assume it difficultly, as medicinal; and those which do not take that Shape at all, as poisonous, with respect to the Blood and its Vessels.



100 *Action of the Lungs.* § 200.

100. The Fluidity will be preserved as well by the Motion of the Globules changing their Contacts, as by their Sphericity, or Smallness of Contacts, with the constant Agitation and Dilution of them in the Lungs.

15 We observed a little before, that the Heat of the Blood was communicated to the Air in the Lungs, and that therefore the Blood was cooled in this Viscus : But in this Place we again assert, that the Blood is heated, as well as cooled, in the Lungs ; which, tho' a seeming Contradiction to the first Assertion, is yet true in Nature. The venal Blood in the left Ventricle of the Heart, is somewhat cooler than the Blood of the Arteries ; and the same venal Blood is still farther cooled by the Air in the Lungs : But the very same Blood, when arrived in the left Ventricle, is warmer than before it was exposed to the Air in the Lungs ; whence it follows, that the Blood must in this Viscus acquire a Heat more than sufficient to compensate the cooling of it by the Air ; which Heat must arise from that increased Attrition the Blood suffers here ; which Attrition is also the common Cause of the Blood's Heat in all the other Parts of the Body. That the Attrition betwixt the Blood and the pulmonary Vessels is very great, may be concluded from the additional Pressure of the Air by which they are forced against each other ; and the increased Velocity with which the Blood flows thro' the Lungs, which are constantly working ; whereas the Contractions of the Muscles are only temporary. This Observation holds true throughout all Kinds of Animals that have two Ventricles in the Heart, and breathe Air into their Lungs, like ourselves ; even the Blood of the Whale-kind of Fish that inhabit the frozen Seas, is equally hot with ours, since they breathe.

But

But those Reptiles and amphibious Creatures which do not breathe, or have but one Ventricle in the Heart, have their Blood near as cold as the Element they inhabit: A plain Argument that the Lungs are the chief Instruments of Heat in the Blood.

¹⁶ We have already shown, that the several Humours mixing with the Chyle (§. 105.) are absorbed, and pass with it into the venal Blood; and that the more subtle Parts of all the secreted Juices which stay any Time in their Receptacles, even the aqueous Dew or Vapours of the exhaling Vessels, are all returned again into the Blood of the Veins, since the Arteries return nothing; but all the venal Blood is propelled thro' the vascular Plexus of the pulmonary Artery, by the right Ventricle, in the same Time that it passes by the Aorta to all Parts of the Body, which at least is after the rate of sixteen Ounces in a Minute; but it is evident, the elastic or spheroidical Particles of the Blood cannot be thus swiftly strained thro' the vascular Plexus of elastic and resisting Vessels in the Lungs, without making a very intimate Mixture and Attenuation of the several Humours therein contained.

¹⁷ The Blood in the pulmonary Artery is venal and dark-colour'd; but when it has passed thro' the same into the pulmonary Vein, it is of a beautiful Scarlet: This additional Redness must have been therefore acquired by the Blood in its Passage thro' the Lungs; tho' the Ancients injudiciously sought for the Cause thereof in the Liver. Various Methods have been taken to account for this greater Degree of Redness in the arterial Blood: Mr. Boyle observed, that Flesh being digested for some Time with Oil of Vitriol turned red, and therefore suspected that something of the like nature happen'd in the Blood: *Lower* and others

derive it from the Nitre in the Air; and various other Opinions have been started. But they none of 'em consider'd that each red Particle of the Blood was globular, and compos'd of six yellow Spherules, made up each of six white Spherules; and that the Blood appeared redder, as there were more of the yellow Spherules compounded together. They also did not observe, that the Blood of those People was the most florid, who were of the strongest Habits, and used the most Exercise. They ought to have been acquainted with what *Leuwenhoek* discover'd, that all our Malt Liquors, Wines, Bread, and all farinaceous Substances do consist, both before and after their Formation into Chyle, of small, lax and white Spherules, easily divisible, which mixing with the Blood, are often discerned floating in it for a little time after a Meal; but in four and twenty Hours after, no such Spherules are discernible in the Vessels, but they are all converted into large red ones, or smaller yellow ones, and still smaller pellucid ones. 'Tis true, the whole vascular System of the Body concurs to this Transmutation; the Veins mix the crude Chyle and Blood, and the Arteries grind them together with a considerable Force: But the Action or Efficacy of the Lungs only, in this respect, is equal to that of all the other Parts of the Body; for the same Quantity of Blood pass'es thro' the Lungs in the same Time that it does thro' the whole Body; and if the Quantity of Blood be compared with the Shortness of the pulmonary Vessels, or Space it runs over, it will give a very great Velocity; to which add the alternate Force or Impression of the Air. Yet are the Lungs not burst by these compressing Forces; for the Dilatation of the Lungs, and the Distention of their Vessels, is universally determin'd or limited by the
Thorax

Thorax and Diaphragm on one Side, and by the Atmosphere on the other. But if you either increase the distending Force of the Heart, or diminish the Pressure of the Air, the Lungs will then be wounded ; for upon the highest Mountains, as the *Pike of Teneriff*, where the Air is exceeding light, the Blood rushes out of the Eyes, Nose and Lungs, because the incumbent Pressure of the Air is diminished without any Abatement of the Force of the Heart, which distends and bursts the Vessels. It therefore follows, that the Lungs are the chief Organs of Sanguification ; in which Operation they always perform as much or more than all the other Arteries of the Body : For you can no sooner increase the Motion and Attrition of the Blood in any of the other Vessels, but the Action of the Lungs will also increase proportionably, Respiration will be quicker, and the Blood transmitted thro' them more forcibly ; nor is it possible for the Aorta to receive more Blood than is derived to it thro' the Lungs. *Lower* indeed computes the Power of the Muscles to be equal with the Action of the Lungs in Sanguification ; but neither can the Muscles transmit so great a Quantity of Blood as the Lungs, nor with that Velocity, nor have they the other Advantages of this Organ ; as, (1.) the Pressure of the Air, computed by *Keil* at an hundred Pounds, acting immediately on the Blood, from which it is separated only by very thin Membranes. (2.) The exceeding Smallness of the Vessels. The Heart is indeed a very strong Muscle, and may be judged to conduce more than the rest to Sanguification, (§. 162, & seq.) Somebody will perhaps object that Fish have no Lungs, and yet they have very red Blood. 'Tis true, the Organs of Sanguification have a different Mechanism in Fish : In them the Heart lies in the Head, in a

fort of Bag, with only one Cavity or Ventricle. A kind of Sacculus receives the Blood from the Vein below, which is instead of a Cava in Fish; which Sacculus contracts and conveys it to the Heart above, which next contracts and propells the Blood into an Artery or Aorta; the first Branch of which goes to the Viscera, and the next dividing into two, sends one of them to the Branchia or Gills, which are Cartilages dividing into a multitude of Arches under the lower Jaw, upon every one of which are extended Branches of this Artery in a reticular Disposition. These Gills in Fish are constantly moving both above and under Water, in the manner of Lungs, whose Office they supply; tho' their Motion is not so great as to generate Heat in the Blood, whose Parts are therefore more elliptic than spherical, and composed of but very few red Globules, or elliptic Spherules. But the Blood of those Animals which have neither Lungs nor Gills is without any Colour. So that this Objection from Fish is so far from opposing, that it confirms my Theory of Sanguification in the Lungs. But lastly, somebody may say that the Blood in a Foetus is red, tho' the Lungs are quiescent. But then the Blood of the Foetus is derived from its Mother, and ought till the Birth to be esteemed a Part of her. If you answer again, that even the *Punctum saliens* in an *Ovum* is red; you urge an Objection the most difficult to solve. But we know from *Pitcairn* and *Bellini*, that the Air penetrates thro' proper Ducts in the Egg; and that if these Ducts are obstructed and deprived of their Commerce with the Air, the Chick will not at all hatch or advance in Growth; and the Eggs of Silkworms will not hatch, even in a warm Place, if you keep them close shut up from the Air in a Glass.

§. 201. If it be asked whether the ponderous and *elastic*¹ Particles of the Air mix with, or enter into the Blood in the Lungs, in order to produce vital *Oscillations*² or Vibrations by their Elasticity, according to *Borelli*; we answer, it is impossible for such elastic Particles to enter the Blood in the pulmonary Artery; nor have we any Reason to believe that such enter the Vein. But it will appear very probable that no such elastic Particles enter the Blood in the Lungs, if we consider the *Compression*³ of the Veins by the Vesicles, when distended with Air, in Inspiration; the compressing Force of the *Thorax*⁴ acting on the Veins in Expiration; the particular manner in which the pulmonary Artery opens or changes into the *Vein*⁵; the very difficult Passage that elastic Air meets with thro' small *Ducts*⁶, which are easily pervious to Oil⁷, Water, or Spirits; with the *lubricating Juice*⁸ of the internal Membrane lining the Trachea; and the pernicious *Consequence*⁹ of such Air when arrived into the Blood. But then may not the very subtle, vapory and attenuated Humours, discharged into the Vesicles of the Lungs by exhaling Arteries, be again *absorb-ed*¹⁰ thence by patulent Orifices, and convey'd into the pulmonary Veins? This indeed seems probable; because even the ceraceous Injection of *Ruyfch* passes thro' the Vein, and transudes into the Cavity of the Vesicles. However, the Air has been sometimes found,

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in a considerable Quantity, in the Heart, its coronary Vessels and the larger Arteries, by *Sylvius* and *Ruyseb.*

I say the *elastic* Parts of the Air; because it is a Chaos or confused Mixture of the Particles of all Bodies: For in it we find (1.) Fire, which penetrates all Bodies, and therefore cannot be excluded from the Lungs. (2.) Exhalations, whose Quantities and Qualities are various and undetermined, and therefore do not come under our Consideration of the Air's Efficacy with regard to Respiration. For the Air is freely respired by the Lungs, as well in the dry Countries of *Arabia* as in the marshy ones of *Holland*. (3.) Water, which readily passes into the Air, but yet we breathe a cold and dry Air more easily than a moist one. (4.) Lastly, the elastic Particles, concerning which our Question is, whether they enter the Veins of the Lungs, mix with the Blood, and then exert their Elasticity, to excite Oscillations therein. But it must be observed, that the same elastic Particles become inelastic, and put on another Nature under different Circumstances; for though these are compressible in the common Atmosphere, and repel each other strongly, in Proportion to their Contacts, yet, when interspersed in the Parts of Liquors, they change their elementary Texture, become inelastic, and afford no Signs of their having any Spring, without the Application of Fire, Freezing, Effervescence, Fermentation; or lastly, the removing so much of the atmospherical Weight as will reduce the Mercury in the Barometer from twenty nine to fourteen Inches Height. That the Air would thus enter into, and become permanent or fix'd in Liquors, was first demonstrated to us by *M. Mariot*, who found this Air in all the Liquors

quors that he could try by Experiment; and has shewn that the Air will enter and fix itself in all Liquors till they are saturated with a certain Quantity, beyond which you cannot force them to take in any more Air. I some Years ago filled a long-neck'd Phial with Water, and forced out its included Air, in Form of Bubbles, by the Air-Pump; but upon leaving the same Water exposed to the Air for twenty-four Hours, it had absorbed as much Air as it contained before; and then, upon Agitation, and endeavouring to force more Air into it, there would not enter one Particle. In this manner the Air, embodied in our Aliments, passes with the Chyle into the Blood; but then it neither exerts any Elasticity, nor produces any Oscillation in the Liquors containing it; and, as the Air never passes in an elastic State into the Blood, it cannot there produce any of the Effects ascribed to it. But the Asserters of elastic Air entering the Blood in the Lungs, bring a capital Experiment to prove their Opinion; viz. they can, by the Pump force elastic Air out of the Blood, taken from the pulmonary Artery, and much more abundantly from the Blood of the pulmonary Vein; whence, say they, the Blood must have taken up a good deal of Air in the Lungs, as it passed from the Artery into the Vein. But they don't consider that their very Experiment makes this elastic Air out of inelastic Matter; and that we are from hence only assured, that the permanent or fixed Air is more easily extricable in an elastic State, from the Blood, after its Attenuation by the Lungs, than before: Therefore their Experiment does not demonstrate more Air in the venal than in the arterial Blood of the Lungs, only that it is more extricable in the former, as *Pitcairn* justly observes.

² *Borelli* observing that the Blood maintained its Fluidity in the Vessels, and congealed after Extravasation, endeavoured to account for the Phænomenon by an Oscillation, or a contracting and dilating Motion in the aerial Particles, exciting an intestine Luctus in the Blood; for, says he, the Air being compressed by the Arteries in their Systole, will, by its Elasticity, re-act and excite a vibratory Motion in the Particles of the Blood. His Hypothesis, tho' too weak to need any Refutation, has yet been inconsiderately received by the *Italians* after him.

³ When the Vesicles are distended with Air, by pressing on the Veins the Blood will resist the Entrance of elastic Particles; and if the Air found Admission into them, it would not inflate the Lungs, but run into the Heart and Blood-vessels.

⁴ For then the Lungs are compressed by the Contraction of the Thorax, which expells the Air thro' the Trachea.

⁵ As the pulmonary Artery and Vein are continuous to each other, without any intervening Cryptæ, or Cells and Ducts large enough to admit any of the Blood; there is no room for any Admittance of the Air here. But yet, as there are exhaling Vessels in the Cavity of the Lungs, discharging an aqueous Moisture; so there are also absorbing ones that admit watery, infectious, and other Particles of the Air; and even by a strong Inflation of the Lungs in the expiring Animal, before the absorbing Ducts collapse by Death, the Air itself will enter by them into the pulmonary Veins, and return to the Heart. But then, in a natural State, the Lungs never suffer such a Pressure as will force the Air itself into their Veins. Therefore no Air enters the Blood by the Lungs
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but in a fixt or permanent State, as it enters and exists in Liquors.

⁶ Thus a Bladder taken out of an Animal will retain Air tho' it transmits Water ; which is an Argument that there are Pores pervious to Liquors and impervious to Air. And Water being forced into the Lungs when they begin to putrify, will transude thro' the Pores of their Membranes ; but as those Ducts are pervious to aqueous Liquors 'tis not likely they should admit Air, for Water resists Air ; and therefore Watermen wet their Sails to prevent the Air from passing through their Pores, to make the greater Pressure. Add to this that the Air entring the Lungs will be resisted by a Mucus lining the Trachea, Bronchia, and Vesicles, so that it cannot pass through the Pores into the Blood-vessels.

⁷ Thus, in the Air-pump of Mr. Boyle, the whole Weight of the Atmosphere cannot press thro' the oiled Leathers interposed betwixt the Junctures ; and it is very easy for the Air to pass through a Mixture of Oil and Water.

⁸ The bibulous Veins of the Bronchia always float in a viscid, mucilaginous Liquor, lubricating the internal Superficies of the Lungs ; but the Air will not enter Ducts that are fill'd with a watery Liquor, and will be still more resisted by the glutinous Mucus.

⁹ For Air being forced into the Veins of an Animal, does, in a little time, obstruct the small Vessels of the Lungs, and cause a fatal Peripneumony ; or else by endeavouring to make its way thro' Ducts that are impervious to it, it bursts them, and occasions sudden Death.

¹⁰ It is by these absorbing Orifices that watery Vapours are often highly serviceable in acute Diseases ; and I know a Remedy which the Lungs thus

thus absorb almost as fast as a Sponge does Water; *viz.* the Fumes of warm Vinegar in a Peripneumony. It is also by this Absorption of the Lungs that contagious Diseases are communicated barely by talking with the Sick; and therefore a Physician ought never to visit such Patients when he is fasting, or his Circulation depressed, because the Absorption is then greatest. But yet I do not think that the permanent Air, which we discover in the Blood, and make elastic by Experiments, is this way absorbed; but enters with the Chyle from our Aliments, which are all of them, both solid and fluid, saturated with inelastic Air, which passes in that State thro' all the digestive or Chylopoietic Organs. This is also more likely than that the Air should be convey'd into the Blood by inhaling Vessels of the Skin, and exhaled again by the Perspiracles of the same Emunctory. Lastly, the strongest Argument to prove the Air is not received into the Blood, is taken from the Experiment I before mentioned (*n. 1.*) that Liquors absorb Air till they are saturated, and no longer; now if the Blood contains Air, as we know it does, it must be either saturated or not; if the last, the Blood in the Lungs will take in Air till it is replete; but then this Air no sooner enters the Blood, than it loses its Elasticity, and becomes fix'd, as in other Liquors: But supposing the Blood to be already saturated, it can then absorb no more Air in the Lungs, and if any be forced into them by Pressure it will remain elastic and prove fatal. I shall now only mention one more Experiment that I made to determine the Point in Controversy; *viz.* we know that by removing the Pressure of the Atmosphere by the Air-pump, the Stomach, Lungs, Bladder, or any other Part which contains ever so little elastic Air, will then swell; I therefore

§ 202. *Action of the Lungs.* III

fore ty'd up a Portion of the pulmonary Artery at each End, before it was cut out, and then put it into the exhausted Receiver, where it appeared to contain no Air, by not making any Intumescence. I did not think the Vein proper for this Experiment because of its absorbing Power.

§. 202. Whether or no the Blood is pro- pell'd into the Lungs, and expos'd to the Air there, to be *cooled*¹, and freed from its fulligi- nous *Fumes*², or to receive some *Spirit*³? Such has been formerly the Doctrine of the Schools; but without any Authority from our Senses, Anatomy, and Thermometers.

¹ The cooling of the Blood in the Lungs, pro- posed by the Ancients and revived by *Cartesius*, comes pretty near the Truth; for since the At- mosphere is always colder than the Blood in the Lungs, from which it is separated only by very thin Membranes, it must inevitably take off some of the Heat; which is also confirmed by a warm Air, equally hot with the Blood, being destructive to all Animals which have Lungs; and it is cer- tain that the human Lungs labour more as the Air is warmer or the Blood hotter than usual, whether the latter proceeds from a Fever, exter- nal Heat, or muscular Motion. But tho' we allow that the Blood is cool'd, or communicates Part of its Heat to the Air in the Lungs, yet you must not imagine this to be the great Use of the Lungs, for it is only an Accident or Conse- quence from the Air; since the Lungs, consider- ed in themselves, are so far from cooling the Blood, that by their Structure and Action they increase its Heat, as much or more than the Air abates

abates it, as appears from the Blood of the pulmonary Vein being warmer than that of its corresponding Artery.

² *Galen* and the Ancients supposed that an innate Heat resided in the Heart, by which the Blood was warmed; and that this Heat was fed or supported by a radical Moisture, which it consumed; whence proceeded those Fumes or Vapours discharged by the Windpipe, as the Smoak of a Fire by its Chimney; and from hence too they deduced that Drought and Blackness of the Tongue and Mouth, observable in many acute Fevers. But this Blackness of the Tongue arises from a Stagnation and Corruption of the thick Juices in the exhaling Vessels of this Organ; whence, if you scrape a black Tongue, the Blood generally follows. 'Tis indeed certain that no inconsiderable Quantity of Vapours are discharged by the Windpipe from the Lungs; but these in a healthy State are altogether aqueous, and partake neither of the Nature of Smoak, Fire, or any other malignant Quality; as is evident from its condensing into meer watery Drops, when ones Breath is blow'd against a Looking-glass, from which the Moisture will entirely evaporate again into the Air, without leaving any Residuum.

³ This Spirit, according to *Galen* and the Ancients, was received from the Air into the pulmonary Vein, by which it passed into the left Ventricle, and there imparted that vital Faculty to the arterial Blood, as enabled it to run into all Parts of the Body. 'Tis certain that elementary Fire, and all other subtle Bodies in the Air, do enter into, and mix with the Blood in the Lungs; but then this is no more than what happens in common to the whole Superficies of the Body, in which there is not a single Pore that can exclude the most subtle

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§ 203. *Action of the Lungs.* 113

Corpuscles in the Air ; which being the common Medium of Bodies, reduces them to the same Temperature ; and I have in my Chemistry demonstrated that at one and the same Time, the Thermometer shews that Gold, Snow, and Wool have the same Degree of Cold.

§. 203. *Sylvius*, and many of the Chemists, have taught, that the Blood becoming almost boiling or scalding by a hot *Effervescence* ¹ in the right Ventricle of the Heart, was drove from thence into the Lungs to be there extinguished, cool'd, and condensed by the cold and nitrous Quality of the Air ; but this their Hypothesis is contrary to Experience. Others have thought that a subtle *Nitre* ² of the Air was mix'd with the Blood in the Lungs, to give it a florid or purple Colour ; of which Opinion was the eminent Dr. *Lower* ; but even this Hypothesis is not much more consonant to Truth and Experience. In the mean Time it is certain, that the Air communicates or performs something more in the Lungs than what we have yet discovered ; for if it be not perpetually *renew'd* ³ it kills the Animal, not from its being heated, rarified, or condensed, but from some other latent Change : *Query*, Whether it is not from the Destruction of its Elasticity ? and whether this is not the secret Pabulum of Life in the Air, so much talk'd of by the Alchemists ? Lastly, It may be ask'd, why a Person cannot breathe under Water, but is quickly *suffocated* ⁴, notwithstanding

ing the Thorax and Lungs remaining capable of an alternate Contraction and Dilatation, by a Continuance of the same Causes, might seem to have the same Action with the Air? This is no easy Question ^s.

¹ We have before shew'd that the Blood cannot receive any such Heat or Effervescence, neither from any Fire of the Heart, nor any Ebullition of the Blood with an acid Chyle, nor with an acid Lymph and Spirits. Vide §. 164 and 18.

² This was the System of *Lower* and *Mayow*, after they had discarded the *Biolychnium*, or *Flammula Vitalis* in the Heart, supposed by *Willis*. Those Gentlemen observing that the Blood in the pulmonary Artery was of a dark red Colour, and of a bright Scarlet in the Vein, inferred that it must have acquired that Height of Colour in passing the Lungs; *Lower* again thought that it must be derived from the Air in Respiration, because the Blood will be thus florid even by one Inflation of the Lungs, but not at all if the Wind-pipe was ty'd. This they thought was the more probable, and even demonstrable, from the Surface of extravasated Blood looking florid, whereas at Bottom or Withinside it looked black, as having had no Contact with the Air; but even the Bottom, after it had been exposed to the Air, became equally florid with the Top; from all which they thought it apparent, that the florid Colour of the Blood arose from the Air; but in the Air they found nothing so likely to produce this Effect as a volatile Nitre, since this Salt floats in the Air, and will also make Flesh look of a red Colour. But I object; (1.) that Nitre is a Salt not volatile with less than 230 Degrees of Heat, and the Air
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is hardly ever so hot as 90, nor is it properly Nitre that floats in the Air but a volatile Acid, which, by meeting with earthy and inflammable Particles, becomes a neutral Salt or Nitre. (2.) It is not the Property of Nitre only to change the Blood florid, but most other saline Substances will do the same, as common Salt, Borax, Tartar regenerated, *Venice Soap*, &c. Add to this, that the venal Blood will appear equally florid with the arterial, only by a brisk Agitation, and after letting it stand still it will become black again. (3.) We are convinced that the Blood becomes more florid barely by increasing muscular Motion; and every Farrier knows what a Difference there is in the Colour of a Horse's Blood that has been a long Journey, and one that has rested a long time in the Stable. The Blood of a cachectic Woman is very watery, and of an obscure red; but by increasing the Blood's Motion with Frictions, Exercise, and Medicines, it recovers its bright Colour again by degrees; whereas without those means it would have continued in its first impoverished State. Some may object, in behalf of Dr. *Lower*, that these means will quicken the Course of the Blood thro' the Lungs, which will therefore impart more of the Air's Efficacy; but this will be little more than a Subterfuge: And we have before demonstrated that the Lungs conduce more to the Redness of the Blood than all the Muscles of the Body (§. 200. n. *ult.*): And (4.) we also demonstrate (§. 200 and 226.) that the red Colour of the Blood does not arise from any Salts, but by the Combination of the pellucid and serous Globules, by Sizes into the larger red Globules, which Combination of the Globules is effected more by the Action of the Lungs than of the Arteries and Muscles, but not at all by any nitrous Salt of the Air. (5.) In-

stead of proving, it is begging the Question, to say that this Appearance of the Blood arises from the Absorption of an aerial Nitre in the Lungs, when we find the same in Fish which neither breathe nor have Lungs; and yet their Blood is sufficiently red; tho' no Proof can be made of any Air being absorbed from the Water which passes thro' their Gills. It must indeed be owned, that Fish have a Bladder of Air, by contracting or dilating which they can either rise or fall in the Water, and sometimes emerge above its Surface; but then no Communication can be demonstrated betwixt this Air-bladder and the Gills, even by the Confession of M. *Du Verney*, who persuades himself that the Gills attract Air.

³ It is an extraordinary Experiment in Pneumatics, that convinces us no Animal can survive long by breathing the same Air that has once entered the Lungs, unless fresh Air be continually supplied to it. For a Bird being included in a Glass with a Thermometer, having no Commerce with the Atmosphere, vomits and dies in less than an Hour, without causing the Thermometer to ascend: And therefore it cannot proceed from the Air being over-heated by the Bird; nor can it be from any venomous or noxious Vapours, since none such can be proved or demonstrated in the Air we have once breathed. What then have we in the confined Air to account for this, but the Destruction of its Elasticity, whence it will not be able to distend the Lungs, nor maintain Fire or Flame, &c. But not only Animals, but even all the Ova, both of them and Vegetables, require a free Commerce with elastic Air to become prolific, which Elasticity they destroy, and therefore require a Succession or Renovation of such Air: Is not this therefore the occult Pabulum of Life, or the Bird of
Hermes,

Hermes, so obvious to all, and yet so long concealed from Mankind. I before observed to you that the Eggs of Silk-worms will not hatch, even in a warm Season, while they remain shut up in a Bottle.

4 When a Person is under Water 'tis evident he cannot let the Air into his Lungs, tho' he may expel most of the Air that is in them; neither will Water be admitted either thro' the Glottis or the Gula, since they will be closed by Instinct, or an unconscious Contraction of their Muscles; but without an alternal Contraction and Dilatation of the Lungs by Respiration, the Blood cannot pass thro' them from the right to the left Side of the Heart (§. 200.); the Blood will then be urged into the pulmonary Artery till it resists the right Ventricle, which will then be unable to empty itself, and remain distended, while the pulmonary Vein and left Ventricle, not receiving their Blood as usual, will remain flaccid and unactive; in the mean time the Aorta and all its Branches will contract and force their Blood into the less resisting Veins, whence the Cava and right Auricle will be distended for want of a Passage to the Blood thro' the Lungs, and therefore Suffocation ensues, or the Blood's Motion ceases. And thus it also is with People who are hang'd; only in them there is a Compression of the Brain also, or an Apoplexy, from the Cord obstructing the jugular Veins.

5 We must not here omit the famous Experiment of Dr. *Hooke*, designed to prove that the Blood may pass through the Lungs without their alternate Dilatation and Contraction. This Gentleman laid bare the Windpipe of a live Dog, whose Thorax was opened, and by blowing into the Lungs with a Pair of Bellows, he found that the

dying Animal by this means came to Life again, and continued alive, though the Lungs were only kept distended with Air by the Bellows; whence he concluded that the Blood passed freely through the Lungs tho' they were quiescent. But we must observe (1.) that the Dr. confesses his Experiment would not hold long without repeating the Inflation; and (2.) that he made several Incisions in the Lungs that the Air might pass freely thro' them without stagnating; and therefore the Experiment is no ways conclusive.

§. 204. But we know both by Causes and Effects, that the Chyle is rather *confusedly*¹ than perfectly mixed in the right Ventricle of the Heart; and that in the left Ventricle they appear more intimately combined: We also know that when the *Lungs*² are strong they duly perform every Thing mentioned at §. 200. but when they are weak or impaired, their Effects on the Blood and Chyle are much more imperfect.

¹ The Blood of the right Ventricle neither appears so uniform nor florid as in the left, and *Lower* tells us he has sometimes found curdled Milk in the former, but never in the left Ventricle or in the pulmonary Vein; whence it follows, that the Chyle and Blood are most intimately mixed in the Lungs.

² In general the Combination and Solidity of the Parts of the Blood arises from the Action of the Arteries and Muscles; but their Attrition is much greater in the Lungs than in any other Part of the Body, since the same Quantity passes in the same Time thro' the Lungs as thro' all the other Parts; whence

whence it happens that when the Lungs are weakened, scirrhus, eroded, ulcerated, consumed, or attached, Sanguification is much impaired, the Blood is more watery, and the Cruor less than it ought to be. Hence in consumptive People the Chyle is neither assimilated nor the Blood compacted, but the Globules of the last separate into smaller, till they run through the small Ducts of the Skin in form of Sweat; and as this Action of the Lungs is analagous to that of Muscles, so it can be only compensated by gentle Exercise and riding on Horseback, or in a Coach upon the Stones, whereby the Blood and Chyle receive the same Attrition in the Vessels as they ought to have in the Lungs.

§. 205. After the Blood has received the Impression of the Lungs in the smallest Arteries, it flows from them into the enlarging Veins, where being less press'd, and urged with contrary Motions, it does, by the Elasticity of its Parts, expand and rarify a little, whence becoming more frothy, red and florid, it passes into the left Auricle and Ventricle.

§. 206. By passing into the left Auricle, though much less than the right, the Particles of the Blood are again mixed in some Degree, and prevented from separating into different Sorts, or from running into Cohesions (as *per* §. 163.): But as the Blood is here more fluid and less liable to Concretions than before its swift Propulsion through the Vessels of the Lungs; therefore the left Auricle

is both *less* in Size and more simple in its Fabric than the right.

† The Smallness of the left Auricle is compensated by the Largeness of the left Sinus, which is as much larger than the right Sinus, as the right Auricle is larger than the left; so that each Auricle and Sinus taken together, are equally capacious to receive and retain the Blood while the Ventricles are in their Systole. But the left Auricle is much weaker and smoother than the right, because the Blood having been but lately attenuated in the Lungs does not want to be farther divided by the muscular Threads, necessary for the more crude and slowly moving Blood of the Cava.

§. 207. The Blood and Chyle thus arriving in the left Ventricle of the Heart with little or no staying by the way; is then, by the contracting Power of the same Ventricle, swiftly and strongly propell'd into the Aorta, and by thrusting forwards the preceding Blood moves the whole Mass.

† The left Ventricle expells about two Ounces of Blood into the Arteries at each Systole; but the Arteries being full, the Aorta must dilate sufficient to receive that Quantity, which Dilatation proceeds instantly throughout the whole arterial System, driving forwards the preceding Blood by that which follows; hence the Force of the Heart seems to be spent on the Arteries only, and not to be extended to the Veins, which are fill'd by the Contraction of the Arteries; which last do, in each Systole, discharge into the Veins somewhat
less

less than the two Ounces they received from the Heart.

§. 208. The Action of the Lungs is therefore of greater moment in a healthy Body than that of any of the other Viscera; since there is not any one Part of the Whole that receives so much as a single *Drop*¹ of arterial Blood till it has been first exquisitely *strained*² through the Lungs: It also appears, that the whole Mass of Juices in the Body pass thro' the Lungs *in the same Time*³ that they complete their Circuit thro' all the other Parts; so that while all the other Viscera receive only a small Portion of the Blood, the Lungs receive and transmit the whole Mass: Hence we discover the Lungs to be the principal Elaboratory of Sanguification, and for converting the Chyle, which is all brought hither, into *nutritious Juices*⁴; in this Organ the whole Mass of Juices receive that Degree of *Fluidity*⁵ and Attenuation which fits them to circulate freely through all the smallest Vessels, and which they cannot receive in any *other Part*⁶; and it is therefore here chiefly that the Blood and its Juices are prepared and fitted to make the several *Secretions*⁷, and to perform all the Actions of Life and Health which depend on the Efficacy of the Fluids⁸.

¹ Even the Heart and Lungs themselves do not receive any arterial Blood for their Nutrition but what has been first strained through the vascular Plexus of the Lungs. The Heart, as a Muscle, receives

receives its Blood from the coronary Arteries in its Basis ; but these arise from the Aorta (§.183.) which receives all its Blood from the left Ventricle after it has passed through, and suffer'd the Action of the Lungs. And the Substance of the Lungs themselves are not nourished by any of the pulmonary Arteries, but by the bronchial Artery of *Ruyfch*, which always arises either from the Aorta or some Branch of it, as the Subclavian, or Intercostal. In short, no Blood is fit for Nutrition, or disposed to pass thro' the several Series of Vessels, but what has lately received the Action of the Lungs.

² All the Blood of the right Ventricle passes into the pulmonary Artery (*per* §. 155.) and all the Blood of the pulmonary Artery is received into the Vein of that Name (*per* §. 198.) ; but all the Blood of the pulmonary Vein goes into the left Ventricle of the Heart, and therefore it is from thence only that the whole Body is supplied with arterial Blood by the Aorta and its Branches. 'Tis true, the Ancients were of Opinion that some of the Blood transfused from the right to the left Ventricle through the muscular Septum of the Heart ; but this Opinion, which was refuted above two Centuries ago, seems to have proceeded from their observing and mistaking the *Foramina Thebesii*, or small venal Orifices in the right Ventricle.

³ The right Ventricle propells its two Ounces of Blood into the pulmonary Artery in the same Instant in which the left throws its two Ounces into the Aorta ; and therefore two Ounces of Blood must pass thro' the Lungs in each Perisystole or Interpause betwixt every Dilatation and Contraction of the Aorta ; otherwise the Aorta would not be supplied with Blood enough from the left Ventricle to be forced into and distend its Branches. It is

is therefore hence apparent that the pulmonary Artery must receive as much Blood as the Aorta. Computing then the Mass of Blood to be twenty Pounds in a healthy Man, whose Pulse beats 3,600 times in an Hour, as the Heart ejects two Ounces at each Systole, the whole Mass of Blood will then circulate thro' the Heart and Blood-vessels thirty times in an Hour, and therefore the same twenty Pounds of Blood must pass thirty times in the same Space of an Hour through the Lungs of such a Man, whereas in Women and Children the Pulse is still more frequent. But if the Blood's Course be accelerated, either by muscular Motion or otherwise, the Lungs will then transmit proportionably more Blood in the same Time than before; from whence their Efficacy in changing the Blood appears to be (*cæteris paribus*) equal to that of all the other Parts of the Body besides; since neither the Brain, Liver, Spleen, Muscles, or any other Viscus, has any Blood but what comes from and through the Lungs. Add to this, that the Force or Action of any of the other Viscera besides the Lungs, is partly employ'd in preparing some Juice for the common Service of the Body; but the Lungs act wholly on the Blood and Chyle, without spending their Force in secreting or elaborating other Juices.

+ From the Chyle only are supplied the vast Quantity and different Sorts of Juices which we daily lose or discharge by Perspiration and the other Excretions; but in order for the Chyle to become nutritious, it must first change its own Nature and put on that of Blood; for without this Change our Blood would be quickly consumed, and we should have only a watery Chyle circulating in our Vessels. But our nutritious Juices are taken into the Blood either immediately by the biliary

bulous Orifices of the absorbing Veins which open into the Cavity of the Mouth, Stomach, and Intestines, or else round by the common Course of the lacteal Vessels, and is then forced all of it through the Lungs, with the venal Blood, before it passes to any one Part of the Body; so that many Parts of the Chyle may often circulate or become nutritious, and perform all their Offices without ever touching or entering the Liver, Spleen, or any other one particular Viscus; whereas none of those Particles can make one Circulation without entirely passing through the Lungs. It therefore follows, that the Chyle is as much changed or prepared for Nutrition by the Action of the Lungs only, as by the Actions of all the other Parts and Viscera in the whole Body. Physicians ought therefore to have a very particular Regard to the Lungs in all Disorders whatever; since no one Malady can happen without affecting them more or less, and since Health, or the due Performance of all the Functions in the Body, depending on the Blood and Juices, arises chiefly from this Spring.

⁵ There are two great Causes of that Degree of Fluidity observable in the circulating Blood; one is the Minuteness of the absorbing Orifices by which the Chyle is taken up and convey'd thither; and the other is the constant Attenuation of them both by the Action of the Muscles and Lungs, but chiefly of the last, which receives vast Quantities and never ceases to labour.

⁶ Because in the Lungs, the reticular Plexus of the pulmonary Blood-vessels, spent on the Vesicles, receives an additional Agitation and Pressure from the Weight and Elasticity of the Air, which inflates them, and does not act in that Manner on the Blood-vessels of any other Part of the Body.

7 We before observed (§. 198.) that it is probable the Lungs have their Blood-vessels divided into the same Number of lesser Series as those in the other Parts of the Body ; from whence naturally follows, that a Disposition or Aptitude is here received by the Parts of the Blood, to form the Secretions, and pass freely through the smaller Series of Vessels in the several other Parts of the Body. For preparatory to Secretion, it is necessary for the Blood to contain a sufficient Number of the Globules of all Sizes, as well of the larger red, and serous ones, as of the many smaller and pellucid or lymphatic ones, that every Series of the Vessels may receive their adequate Globules ; or that while the larger red Globules are passing on through the sanguiferous Artery into the sanguiferous Vein, the smaller serous Globules may pass off laterally into their lesser lymphatic Arteries, of all the Orders. For without Juices adequate to pass the Sizes or Diameters of the Vessels, those Vessels would be useless, and the Parts they compose become incapable of their Actions ; and even the Nerves would be all useless without a Supply of Globules small enough to pervade their minutest Tubuli. But the Lungs make all the different sized Globules of the Blood, not only by dividing the larger into smaller ones, but also by moulding or wire-drawing each of them through its several Series of Vessels, adequate to the Diameter of each Set of Globules. But the Lungs do not only generate or frame each Set of Globules, but they also compact and polish them, so as to increase their specific Gravity beyond that of Water : And how essential the specific Gravity is to the determinate Nature of every Body is obvious to all ; for could we make Mercury 19 times heavier than Water we should not be far from making it Gold.

* All this is to be understood of the Lungs in an Adult; for in the Fœtus, whose Lungs receive no Air, no more Blood passes through them, in Proportion to their Bulk or Number of their Vessels, than thro' any other Part of the Body; and therefore the Action of the Lungs on the Blood, which we have been here describing, does not take place in the Fœtus:

§. 209. All these Effects (§. 208.) follow from the determinate Nature of the Blood and Chyle, from the known Fabric and Action of the Lungs, and from the determinate Force of the Heart, with the known Pressure of the *Air*¹, acting as a heavy and elastic Fluid, first on the Air-vessels of the Lungs, and by them also on the Blood-vessels.

¹ Thus you have all the Effects of the Lungs, enumerated in §. 208, and explained by their Fabric and the Action of the Air in §. 200, besides which, we require no other Cause to account for their known Effects or Appearances.

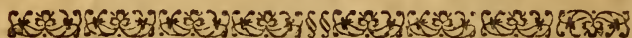
§. 210. What Occasion have we therefore to suppose any Mixture of the Air, or an aerial Ferment with the Blood in the Lungs? If you ask, whence comes the Air discovered several Ways in the Blood? We answer, from the same Cause by which it enters into all other Liquors, *i. e.* by Attraction or Absorption. But if your Question is, Whether it has any Action, as Air, in the Blood? we answer, that no such Action of it seems probable there, unless its small Particles resume their
Ela-

Elasticity, and run together into little Bubbles.

§ 211. Lastly, To what else, than the preceding Action of the Lungs, can we chiefly ascribe that Change in our Aliments which makes them nutritious, or of an animal Nature, capable of yielding an acrid and *volatile* Salt? This Change or Volatization was indeed long ago observed by *Helmont*, who also derived it from the Action of the Air, but not in a just manner. Upon this Subject, the Lungs, you may peruse the Writings of *Belini* and *Pitcairn*, with those of *Malpighi*.

Every Animal either lives immediately on Vegetables, or else feeds on the Animals which themselves feed on Vegetables; (*Vid.* §. 95. N°. 11.) but vegetable Substances do all afford a fix'd alkaline Salt by Fire, whereas all animal Substances yield a volatile alkaline Salt. But these fixed Salts are volatilized in the animal Body; for in the Urine and Fæces of a Maid who had the Green-sickness, and took, by my Order, two Drachms of fixt Salt daily, no other than volatile Salts was found. And the little graniverous Bird we call a Sparrow, though fed on vegetable or acescent Substances, that yield a fix'd Salt by Fire, affords none but volatile Salts by Distillation, nor can any other Salt be had from its Dung. This Change or Volatization was, by *Helmont*, judged to arise from the Air, because he had observed that a fix'd Salt exposed to the Air melted or dissolved, and that by drying it at the Fire, and then exposing it to the Air again, for ten Times successively, it at last became volatile, and wholly exhaled
into

into Vapours, leaving an Earth. But we derive the Volatization and Change of Vegetable into animal Substance, barely from an Attrition of their Parts ; for if any Plant, yielding only an Acid and a fix'd Salt, be laid in a Heap, it putrifies, not without growing so hot as to be almost intolerable to the Hand ; now we know that Heat always arises from Attrition, and therefore Attrition is the Cause that renders fix'd Particles volatile. But the alimantal Juices in the human Body suffer the greatest Attrition in the Lungs (*per* §. 200 and 208.) and therefore it is by them chiefly that the fixed Particles are volatilized, and those of Vegetables changed into animal Substance.



*Concerning the Action of the Arteries
or their contained Fluids.*

§. 212. **I**N order to understand what further happens to the Blood and Chyle, now moving forwards in the Aorta and its Branches, we ought to be previously acquainted with the Principles and Laws of Hydraulics, by which all Liquors, moving with a certain Velocity through known Vessels, are determined in their Courses or Directions towards particular Parts ; but to demonstrate these Laws of Motion in Fluids, to which all Liquors are subvervient in their passing through Vessels of any kind, is the Business of *another Place* ¹, or rather the Province of Mechanics.

The

The several Velocities, with which our Juices move through their Vessels, are estimated from the Causes and *Effects* ¹ of those Velocities, observed either by our Senses, or discovered by just Reasoning. But the Structure and Action of the *Vessels* ³ themselves, containing Blood and Juices in Motion, are discover'd either by Sense and *Reason* ⁴, assisted with Microscopes and *Injections* ⁵, or by the following Rule of Analogy, *viz.* that in the human Body you may judge of the invisible Parts by those which appear visible.

¹ To become a Proficient in Physiology, one ought to be not only well acquainted with Mathematics and Mechanics, or the Doctrine of Quantity and Motion in general; but also to understand the Nature and Action of the Arteries, and of the Blood moving through them. In order to this we may observe, I. That in all Bodies there is a certain *Vis* or Power by which they generate Motion, and is reducible to the following Heads: (1.) The *Vis inertia*, by which all Bodies endeavour to remain in the same State, either of Rest or Motion; (2.) the *Vis Gravitatis*, or Gravitation, by which Bodies tend towards the Center of our Earth; both which Powers are always proportionable to the Quantity of Matter in any Body, because they are equally diffused throughout all the Particles of Matter, and therefore one Body that is twice as heavy as another will require double the Force to move it, and will retain its Motion twice as long. II. The *Extension* and *Figure* of a Body has a vast Influence on its moving Power; for a Body that is the most compact, or has the least Surface, will strike with the great-

est Force, and be most retentive of Motion. And even Gold itself, that is nineteen times heavier than Water, may be made to swim in that Liquor, by only beating it into Leaves with the Hammer.

III. The Power of *Elasticity*, peculiar to some Bodies only, by which they give way to any Force or Pressure, and return again when the Pressure ceases ; this Power also enables Bodies to multiply or return the Motion first received.

IV. The Structure or *Mechanism* in the Parts of a Body, by which the same Matter may be enabled to give different Effects and Appearances, not explicable by the general Laws of Matter and Motion alone ; as when the contrary Forces of Gravity and Magnetism are opposed to each other in a Machine.

V. The *Vires monadicae* of Bodies, by which they attract and repel each other electrically or by Magnetism, a Power independent of Gravity, and not yet accounted for by any one.

Besides these, one that would explain the Action of the human Body must take into Consideration (1.) the anatomical Structure of the Arteries (§. 132.); (2.) the intrinsic Nature of the Blood, and that which it acquires by Motion from the circumambient Parts: (3.) The Elasticity and *vis inertia* of the Vessels: (4.) The Gravitation of Liquors, and their Tendency to an Equilibrium: And (5.) the hydraulic Powers arising from the Vessels and Liquors conjunctly.

By these we are taught that a Liquor moving through a Tube or Vessel, every where of an equal Diameter, meets with no Resistance from the Sides but that of Friction ; but in a Tube whose Diameter or Section is continually lessening, the Resistance of the Fluid gradually increases, and is greatest where the Section of the Vessel becomes smallest, *i. e.* at the Apex of the converging Cone, whence the Liquor being urged on in

distractile

distractile Vessels of this Figure, will distend or dilate them; but in Vessels gradually diverging, both the Resistance and Friction of the Liquor continually lessens. Lastly, (6.) the Action or Force of the Arteries ought to be considered; but in this great Caution is required; as may appear from the Attempts of some to compute the Force of the Heart from the Quantity and Height of the Jet of Blood flowing in a given Time from a wounded Artery in a Dog or an Ox; but in this Estimate they did not consider, that the Force or Velocity of the Jet is lessen'd, as well by the Wound of the Artery, as from the Diminution of the Impulse of the Blood to the Cerebellum. But the Misfortune is, that such physiological Subjects are usually handled either by Mathematicians unskilful in Anatomy, or by Anatomists who are not versed in the Mathematics.

² As we know by Experience that the Heart contracts 3,600 Times in an Hour, and throws twice as many Ounces of Blood into the Aorta in that Time, we could easily compute the Velocity of the Blood, did we but know its determinate Quantity circulating in the Body: For the Velocity or Quantity of Motion in any Body is always in Proportion to its Weight and the Space it runs over in a given Time. But the Degree of the Blood's Velocity may be also discover'd by its Heat, which increases in Proportion to the Strength and Frequency of the Pulse, or Systole of the Heart. And thus it is even with all other Bodies, having any Contact or Friction of their Parts; for then they heat in Proportion to the compressing Force and the Velocity of their Motion.

³ The State of the Vessels is a material Consideration, whether they are rigid, like wooden Tubes, or ossified Arteries, or whether they are elastic and

distractile, like our Blood-vessels in their natural and healthy State. In the rigid or immoveable Tubes, we are taught by *M. Amontons*, that the Fluid has no other Action on the Vessel, nor the Vessel on the Fluid, but that of Friction. Some of our Arteries and Veins are not equally distractile, from their being seated near resisting Bones or Cartilages, like the carotid and vertebral Arteries; nor in these do we observe more than a reciprocal Attrition betwixt the Fluid and Vessel. These distractile Vessels are again either converging, as the Arteries; of the same or an equal Diameter, or else diverging, as the Veins, *per* §. 132, and *seq.* The Blood meets with a Resistance, continually increasing in the converging Vessels, but only from Friction in the cylindric ones, and continually decreasing in the diverging Vessels. Lastly, the Liquors themselves are to be consider'd; for if these are at rest, they act only by their Weight, but if they are in Motion, they will act equally on every Point of the Vessel, and be equally repelled again from every Point of the same Vessel. The smoothness of the Arteries within-side, and the globular Texture of the Blood, prevent the Friction from being too destructive; but then the Glutinosity of the last, and the Elasticity of both, excite that Attrition which renders the Blood warmer than other Liquors.

4 Dr. *Herman* has demonstrated that a right Line pressed equally on every Side will form a Circle; and thus a Bladder being placed betwixt two concave Hemispheres, and fill'd with Water, will be distended into a Sphere: But as our Arteries are distended by the Parts of the Blood, impell'd and acting in all Directions like the Radii of a Sphere, therefore they are always circular; tho' the Case being otherwise in the Veins, many of them

§ 213. *Action of the Arteries.* 133

them are triangular, oval, or variously figured. But the Arteries are so retentive of their Sphericity that, rather than part with it, they make semicircular Excavations in the hard Bones of the Skull ; for the soft Bones of the Foetus have none of those *Sulci*, but as they grow up, the Expansion of the Artery exceeding the Force of Accretion or Growth in the Bone, makes an Impression by obstructing the same where it strikes.

5 The Inflation of Air into the Vessels, which is one kind of Injection, was known to *Galen* ; but *Eustachius* seems to have been acquainted with a more perfect Method of injecting, from the great Exactness with which he has traced the Vessels, *Vid.* §. 134. But the first who brought ceraceous Injections into anatomical Uses was the industrious Dr. *Swammerdam*, and the celebrated *Ruyfch* has carried the same to the highest Perfection, demonstrating by his Injections that the smaller and invisible Vessels are like the larger and naturally conspicuous ones.

§. 213. An Artery then, described in §. 132, dilates or *expands* ¹ by the distending Impetus of the Blood, and when that Impetus ceases, by its Elasticity it naturally contracts or *returns* ² to its former Capacity ; for if the Finger be thrust therein, it forcibly compresses the same, and again contracts itself when the Finger is withdrawn. This Vessel therefore appears *full* ³ of Blood in the living Animal, but is found very *small* ⁴ and almost empty in a dead human Body, even tho' none of the Blood was lost ; it also resists Inflation, forcibly *repelling* ⁵ the Air that is drove in, and

contracting to its least Diameter, it then stops ⁶ or stands still; so that the contractile Power of this Vessel arises from the elastic Nature of all its component *Fibres* ⁷, as well from the most simple and minute as from the more complex *Fibres*, formed out of the preceding, or by some of the smaller Vessels concreting with their inspissated Juices; and lastly, from a Repletion of the small *Vessels* ⁸ spent on the constituent Membranes of the Artery itself.

¹ The contractile Force of the Heart overcomes the Resistance of the Aorta, and by that means throws as much Blood into the latter, as itself received from the venous Sinus: Thus the Arteries will be expanded every way, in Proportion to the Quantity of Blood received; but they will not dilate so much longitudinally as laterally, because the resisting Bones determine their Length, the Arteries being full and conide, the Blood will strike in Lines perpendicular to their Sides, which will therefore yield.

² The Arteries are elastic Tubes (*per* §. 132.) but Elasticity is the Property of Bodies by which they recover their former Position, when displaced by any Force; as when a tense Chord is forced out of its rectilinear Position so as to form an Arch or Angle, whose Periphera is always greater than a right Line: So that by this Extension the Particles of the Chord will recede from each other's Contact in that Proportion which the Arch or Angle bears to a right Line; but when the distending Force ceases; by the Attraction of Cohesion in the Particles, they will run into larger Contacts, and shorten the Chord, by reducing it to a right

right Line. 'Tis in this manner that all the Arteries act; for the Sides of these being circular, they are distended, in every Point, by the Impulse of the Blood from the Heart, into larger Circles; but that Impetus from the Heart ceasing (*per* §. 185.) each elastic Circle or Segment of the Artery will return or contract, and propell the Blood as well towards the Heart as the Extremities; but the Resistance being less towards the last, by their opening into unresisting Veins, it passes only that way. This contractile Force in each Artery is, *in general*, stronger as it is nearer to the Heart or Basis of the Aorta; for there the Coats are strongest, and the Dilatation greatest, to which the Restitution must be always proportionable. I say in general, because there are some Arteries near the Heart, much weaker than others, more remote; as the Coronaries, Intercostals, &c. Hence every Circle or Segment of the Aorta and its Branches seems to act successively, propelling the Blood from the greater to the less resisting, but so swiftly as to be imperceptible to us in the Pulse.

³ The Arteries are always full; even in their Systole they are equally full, though they then contain less Blood than in their Diastole; and upon opening a living Dog the vibrating Aorta appears larger as the Animal has more Life, and acquires a smaller Diameter as he is nearer Death. In consumptive People there is often no more than a few Ounces of Blood in their Vessels, to which small Quantity the Arteries gradually contract and adapt themselves, so that they become almost imperceptible and like small Threads, the Skin at the same time adhering to the Bones; and yet there are here none of the solid Fibres consumed, except those destroy'd by Putrifaction in the Lungs. And in the same manner do the Arteries also con-

tract themselves to the waſting Juices in many other lingering Diſorders. But were the Arteries to be ſo much evacuated of a ſudden, they would not contract to ſo ſmall a Diameter, and at the ſame time preſs with Force enough on the Blood to make it perform all its neceſſary Functions; thus the Impulſe of the Blood to the Cerebellum being diminiſhed, from whence the Heart receives its Force, a Deliquium or Death would enſue, even though but a ſmall Part of the Maſs were exhausted, from a Perſon of lax Veſſels. Hence too, you may perceive the Inſufficiency of the Method propoſed by Dr. Keil, to eſtimate the Velocity of the Blood by the Diſtance to which a certain Quantity flies in a given Time from a wounded Artery of a known Diameter; for in this Experiment the Action of the Cerebellum is firſt gradually diminiſhed, and then the Force of the Heart likewise, on which the Experiment is founded.

4 In the dead Animal the Arteries appear ſmall or contracted, white, with little or no Blood in them; becauſe by their greater contracting Force they protrude their Contents into the leſs reſiſting Veins; therefore the Blood of the dying Animal will be chiefly accumulated in theſe laſt, which will appear turgid.

5 It reſiſts Inflation with the ſame Force that it reſiſted the Impulſe of the Blood in the living Subject; and repells the Air again as forcibly as it propell'd the Blood in Life; becauſe in its Syſtole it returns to its firſt ſmall Diameter; otherwiſe the Artery would continually enlarge at each Diaſtole, as it does in the Formation of an Aneurism, or after a Wound.

6 For a circular Fibre can never contract itſelf ſo as to have no Cavity, but only till its conſtituent Elements, or ſolid and earthy Particles come
into

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into the closest Contact, for they cannot enter into one another.

⁷ Which being very robust, are disposed circularly round the Artery, (*per* §. 134.) whose Diameter they contract.

⁸ The Coats of the Arteries, especially of the larger, are replete with small Blood-vessels coming from the Coronaries, and from the Parts to which the arterial Trunks are connected. These running or spreading themselves through the cellular or second Tunic (§. 132.) of the Artery, appear so numerous when distended with the Injection of *Ruyseb*, that one would imagine them to make up the greatest Part if not the whole Substance of the Vessel. 'Tis remarkable that these small Arteries of Arteries are in their Diastole when the Arteries they compose are in their Systole, which Action they forward by their Turgescence; but when the larger Arteries are dilated, these small ones, spent in their Tunics, are compressed, and their contained Blood evacuated, like the coronary Arteries of the Heart (§. 183.) see more at §. 132. N^o. 8. Besides these, the Contraction of the Arteries is also assisted or promoted by the Elasticity and Compressure of all the adjacent Parts contiguous to the Artery, and which it removes into its Diastole, whose Force will shake the whole Limb, if you lay the Ham of one Leg over the Knee of the other.

§. 214. Nor is there *any* sensible Part throughout the whole Body, but what is furnish'd with some small Artery; as we are assured from *Wounds*², *Microscopes*³, and *Injections*⁴: Even in the very middle of the Bones do we find the same Membranes, Vessels

sels and Fluids, as in the other Parts; but all these small Arteries, every where observed, are little Branches of the *Aorta* ^s.

¹ *Galen* and the Ancients distinguished many Parts of the Body by the Name of Spermatic, which they supposed, even till the last Century, not to be nourished from the Blood; but these Parts have been since demonstrated by the Industry of *Ruyfch* to consist almost entirely of Vessels capable of receiving his ceraceous Injection, by which he shews that even the compactest Bones, Cartilages, Membranes, Ligaments, and Tendons are all furnished with the same Arteries as the softer Parts, only many of them seem too small to admit the red Part of the Blood.

² One cannot enter the smallest Needle through any Part of the Cuticle but the Blood will follow it; but this Blood issues rather from the small Arteries than the Veins, because the former extravasate it with the greatest Force; whereas the Veins, even pretty large ones, discharge but little Blood and but slowly.

³ By these we are enabled to see an infinite Number of small Arteries, with the Blood running through them, in the Tails and Fins of little Fish, and in such other Parts as one would otherwise take to be mere membranous Expansions.

⁴ By the Artifice of Injections, a most admirable Improvement in Anatomy, we discover every Part within the Cuticle to be vascular. The Preparations of the celebrated *Ruyfch*, who has industriously excell'd in this Practice, shews the otherwise pellucid Membranes to be beautifully painted with Ramifications of Arteries; even the hard Tendons and compact Ligaments being cut in sunder after they have been injected, demonstrate ma-

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ny small Arteries running through their Substance. That indefatigable Anatomist has even injected the white and solid Cartilages of the Bones, after macerating them eight Days in Water, made a little salt to prevent Putrification.

⁵ I need hardly observe that in the Liver and Lungs you may in some measure make an Exception; but even these are plentifully furnished with Arteries from the Aorta; in the Liver, *Ruyfch* has demonstrated a vast Number of small Arteries from the Cystico-hepatic, Ligamentary, Pericardio-diaphragmatics, &c. but in the Lungs his bronchial Artery is ramified throughout.

§. 125. The Blood being propelled into the Aorta, meets with a Resistance from that with which the Arteries are already *fill'd* ¹, as also from the *Incurvations* ², *Elasticity* ³, and *conical Figure* ⁴ of the Arteries, with the Resistance of the contiguous Parts, *pressing* ⁵ on the Arteries by their Weight and elastic Nature, and lastly, from the exceeding *Narrowness* ⁶ of the smallest Vessels: So that this Fluid passes through the Vessels only by the *Excess* ⁷ of the Force given it by the Heart above the Sum of all the Resistances; but as these Resistances are less in the *Lungs* ⁸, the weaker Contraction of the right Ventricle is therefore able to propell the Blood more easily through them, considering this Viscus barely as a Part of the Body, or as it exists in the Fœtus in Utero, without any Regard to its Office of Respiration.

1 Were the Arteries quite empty, the Blood would then meet with little Resistance in them, and no great Force of the Heart would be required to fill them; but the Arteries of a Person in Health are always full (*per* §. 213.) as well in their Systole as Diaſtole: For were only some of them empty, the Blood would ruſh into them ſo impetuoſly as to cauſe a Rupture; or were only ſome Arteries leſs full than others, the Blood would even then deſert its Courſe to the Brain, and fly to the leſs reſiſting Veſſels, whence would follow a Deliquium, as is the Caſe in a profuſe Hæ-morrhage, or Phlebotomy. The Blood therefore which is thrown out of the Heart drives forward the reſt already in the Arteries; but that the Quantity of Blood and Juices thus moved at each Syſtole of the Aorta is very large, may appear from their being much ſuperior to the whole Maſs of Solids, according to the Computation of Dr. Keill; and one may, at a moderate Eſtimate, compute that in a Man weighing 200 Pounds, there are not above 110 of Solids, including the Skin and Fat; ſo that there will then remain 90 Pound of Juices which reſiſt the Blood thrown out of the Heart into the Arteries at each Syſtole. Even the ſolid Hoof of a Horſe is not ſo compact nor dry but if the Farrier ſhaves it too deep it bleeds very profuſely.

2 Some Geometricians affirm that by Experiment a Liquor paſſes as ſoon, or in the very ſame time, through an inflected Tube, as through one that is ſtreight. The Difference may indeed be granted very imperceptible in Tubes that are ſmooth, rigid and not elastic, but every where cylindrical and of an equal Diameter, and with Liquors having but little Cohesion or Viſcidty; but
it

it is otherwise betwixt the Blood and the elastic or inflected Arteries of the human Body, which being frequently complicated or incurvated at right Angles, make a great Resistance to the Course of the Blood.

³ So great is the Strength and Resistance of the Arteries, that the larger Trunks can scarcely be distended with Water by any Force; and their Resistance would be probably too great for the Heart to overcome, if they were not continuous to the Veins, where the Resistance of the Blood from the Sides of the Vessel continually diminishes.

⁴ In a Tube whose Shape is that of a converging Cone, like the Arteries, it is universally allow'd that a greater Force is requir'd to dilate the Sides as the Force is apply'd nearer the Apex or Extremity. But we have here usually two Objections made: (1.) That the Diameter of all the small Arteries taken together greatly exceed that of the Aorta next the Heart, and that therefore the arterial System is not to be considered as a converging Cone, but rather as a Cone diverging. But we answer, that the Arteries have from their Shape, notwithstanding the Friction and Resistance proper to a converging Cone; for they are dilated more near the Heart than towards their smaller Extremities, which is not the Property of a diverging but of a converging Cone; and we find, by Experiment, that the Diameter of the Aorta is proportionably more increased near the Heart than at some Distance, and that the Branches dilate still less in Proportion, and the Capillaries least of all. (2.) The second Objection is, that all the Arteries have not a conical Figure; for the carotid passing to the Brain through a bony Canal is there contracted, and again dilated or enlarged within the Cranium, and then again contracted.

tracted. But we answer, that even the Carotid has a greater Dilatation near the Heart than at the Brain, and if it any where puts off the Figure of a converging Cone, we need not wonder that it should also be without its Affections; but then this is true only in the Part of the Artery thus changed from its common Shape and Disposition.

⁵ Besides the Pressure on the Arteties from the adjacent Bones, Muscles, Fat, &c. they are also compressed by the Atmosphere, which they remove with the adjacent Parts in every Diastole; which considerable Pressure of the Atmosphere only, is equal to the Weight of a Column of Water thirty two Feet perpendicular. Some indeed deny this Pressure of the Air, notwithstanding it is so evident; because, say they, we do not perceive any such Pressure on our Bodies, which is owing to the Resistance of the internal Air included in our Bodies sustaining the Weight of the external; but it is certain that when the Pressure of the external Air is removed from any Part by Cupping-glasses, or otherwise, the Blood and Juices rush more violently into the Vessels of that Part than of any other, from their less Resistance by removing the Pressure of the Air. 'Tis also well known that all Animals swell surprisingly in the exhausted Receiver of an Air-pump from the Juices running more copiously into the Vessels of the external Parts, which by exhausting the Air have a less Pressure and Resistance against the Blood. Nor do we know of any Part besides the Lungs which contains Air truly elastic, and none but such is capable of resisting the Weight of the Atmosphere, and of supporting the Parts of our Bodies against its Pressure.

⁶ A Liquor flows with a much greater Velocity through two or three Tubes of a determinate Capacity than through a great Number of small Tubes whose Lights or Diameters added together are equal to the former ; for it appears, from the Principles of Hydraulics, that to fill or distend an hundred small Tubes requires a much greater Force than to fill one Tube of the same or equal Dimensions : Nor is it difficult to account for the Phænomenon which arises from the greater Friction and Resistance of the Liquor against the increased Surfaces of the Tubes, or Cylinders, a large Tube having a less Surface in Proportion to its Contents than a small one ; so that if an hundred Globules were to pass through a certain Tube, only a few of them which lay next the Tube would suffer the Resistance of Friction from its Sides, but if that Tube was ramified into an hundred, all pervaded by the same Liquors, then every Individual Globule would suffer a vast Friction, by coming into contract with each Tube, whence the Friction would be surprisingly augmented. And thus it is with the Arteries of the human Body.

⁷ The Force of the Heart is more than equal to the Resistances, arising from the Blood already in the Arteries, from their conical Figure, various Inflections or Incurvations, Elasticity, and Smallness, or the Multitude of Ramifications, with the Pressure of the Air and circumjacent Bodies ; for was the Force of the Heart barely equal to these Resistances, according to Dr. Keill, the Blood would then stand still from the Equilibrium ; but we find that it moves forwards in the Vessels with a Velocity equal to the Excess of the Heart's Force above those Resistances.

⁸ For an equal Quantity of Blood is propell'd through the Lungs, by the weaker right Ventricle

cle of the Heart, in the same time that a like Quantity is propell'd throughout the whole Body by the stronger left Ventricle (*per* §. 184.); whence it follows, that the Blood meets with less Resistance in the Lungs, partly from the Air's sustaining the vascular Plexus spread on the Vesicles of this Viscus, and pressing less on them than the cutaneous Vessels, and partly from the pulmonary Vessels being fewer in Number and less inflected than those of the whole Body besides.

§. 216. From what has been said we must therefore conclude the Power of the Heart to be very considerable, as well from computing the Force by which it overcomes or *exceeds* ¹ the several Resistances, as from considering barely the vast Quantity of Juices *to be moved by it* ².

¹ It is by this Excess of Force that the Heat of animal Bodies is generated; when at the same time Water never acquires Heat tho' moved with the greatest Velocity, even in the magnificent and regal Water-works and Engines at *Versailles*, erected by *Lewis XIV.* But the Difference betwixt these Hydraulic Engines and those of animal Bodies, productive of Heat, is, that in the last both the Tubes and Juices are elastic, the Particles of the Blood and Juices are very viscid and adhesive to their Sides and to each other, the Vessels infinitely ramified and inflected into converging Capillaries; by all which the Frictions and Vibrations both of the Vessels and Juices are so far increased above the former, as to produce Heat, always proportionable to the Blood's Velocity and Diameter of the Arteries through which it passes; for in a large

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large Artery where the Blood moves swiftest there is little Friction, but in the smaller Arteries where it moves slowest there is a greater Friction, whence the Equality of the Blood's Heat both in the larger and the smaller Vessels.

² So abundant that Dr. Keill computes nine Parts out of ten are Juices in the human Body; and by a more moderate Computation there are 90 Pounds of Juices circulating by the Force of the Heart in a Man weighing 200 Pounds.

§. 217. Since therefore the whole Mass of Blood is drove forwards with so great a Force (§. 216.) and again *repell'd*¹ by so many and great Resistances (§. 215.) in passing through a full, conical, *pliable*² and very elastic Vessel; it therefore necessarily follows that the Dilatation of this Vessel or Artery is contemporary with the Contraction of the Heart, and that this Dilatation, which is the natural and unactive State of the *Heart*³, is the preternatural or *violent*⁴ State of the Artery; and that this Dilatation of the Arteries is performed in every Part of a healthy Body at the *same Instant*⁵ of Time, as we are assured from their being all full; but then this Distention of them is the most perceptible where the Arteries are found seated upon hard resisting Bodies, as the Bones, and where they lie most *exposed*⁶ or uncover'd.

¹ If the Blood met with no Resistances in the Arteries, it would pass freely through them into the Veins without ever distending them; but by their Figure, Plenitude, and other Affections the

Blood is forced against their converging Sides, which consisting of circular and elastic Fibres are equally dilated from a smaller to a larger Diameter, and that even without any shortening of the Arteries, which are kept extended to their full Length by the resisting Bones.

² Were the Arteries to become rigid, Death would be the Consequence, because the Heart would not be able to overcome their Resistance; and this it is that occasions Death from mere old Age as well in human as brute Animals; *viz.* the Arteries become too tough and rigid by their frequent Action, the Tendons become inflexible and indisposed for Motion, and the Cartilages turn bony, &c. *Vid.* §. 468, and 475.

³ For this hollow Muscle is naturally flaccid and dilated, like all other Muscles, when at rest; but its Contraction follows from other Causes not within itself, *viz.* the Force or Influx of the nervous Juice from the Cerebellum, and the Impulse of the arterial Blood impell'd by the Aorta into its coronary Arteries, *per* §. 187, and 190.

⁴ As arising from the Impulse of the Blood given by the Force of the Heart; but when that Impulse ceases, the Artery being left to itself contracts by the Elasticity of its Fibres, and then stops a while in its greatest Contractions, *per* §. 132.

⁵ Mathematically speaking, they do not absolutely all dilate at the very same and least Instant of Time as the Motion is successive, but the Difference is not sensible in a healthy Person; tho' in one that is dying, the Heart and larger Arteries beat when you can perceive no Motion in the smaller Arteries of the Limbs. To express the imperceptible Variation of Time, the 3,600th Part of an Hour must be divided into an infinite Number of
Parts

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Parts, and again divided proportionable to the Distances of the Arteries from the Heart ; but I will not insist on speculative Subtilties.

⁶ Because those resisting Bodies return the whole Diastole of the Artery upon the Finger of the Physician ; thus it is in the Arteries of the Temples, Carpus, Angles of the lower Jaw, inner Corners of the Eyes, &c. but when the Artery is invested with much Fat, its Ictus is lost in that soft Substance, and makes little or no Impression on the Finger ; whence the Pulse of a lean Person will seem four times as strong as that of a fat one, tho' in themselves they are both of equal Strength, and the Persons equally in Health.

§. 218. But while the Artery is in this Diastole or Dilatation (§. 217.), it exerts a strong *Reaction* ¹ by its elastic Power (§. 213.) in a contrary Direction, and being assisted at the same time by the resisting Power of the circum-ambient Parts (§. 215.), the Artery will consequently contract, and forcibly propell the Blood, as well by its own (§. 213.) as the received Pressure, without which the Blood would stagnate ; and from this Power therefore of the Artery its contained Blood runs forwards in a Stream continued, but somewhat starting, especially at the Instant of the Heart's Contraction : This State of the Artery is call'd its Systole, being Contemporary with the Diastole of the Heart, and makes the *natural* ² or unactive State of this Vessel, whose Contraction is assisted by the Meeting or Return of the *Valves* ³ in the Aorta, and the *Emptiness*

and *Flaccidity* ⁴ of the coronary Arteries. But during the Contraction of the Heart, the Arteries and Veins contain as much more Blood than during its Diaſtole, as will fill the two Ventricles, which Quantity they protrude into the Arteries at each Contraction, beſides the Blood expreſſed out of the coronary Veſſels of the Heart; but on the contrary, when the Heart is dilated and the Arteries contracted, the Veſſels contain ſo much leſs Blood than before; that Quantity being poured into the Ventricles; whence you may compute the Difference of Capacity in the Arteries when in their Syſtole and Diaſtole.

¹ This Re-action may be compared to and underſtood by that of a tenſe Chord, ſtruck or forced by ſome Weight; but if we conſider the greater Ratio or Proportion that the right Auricle bears to the left, *viz.* as 5 to 3 according to *Santorini*; it will not ſeem improbable that the right Auricle is ſo much larger to ſerve as a Diverticulum to the venal Blood, when it is ſent faſter to the Heart than it can protrude it through the Lungs, as in ſudden Exerciſe, Fear, Cold, &c.

² A State which the Artery acquires of itſelf and of its own Nature, whereas the Diaſtole ariſes from a Cauſe not in the Artery but in the Blood, *viz.* the impelling Force of the Heart.

³ When the Aorta contracts itſelf, it preſſes the Blood every way as well towards the Heart as the Extremities; but to prevent any of the Blood from entering the Heart again out of the Aorta, which would confound the Action of the Muſcle, the ſemilunar Valves meet ſo exactly as not to admit

mit one Drop to pass betwixt them; by which means the whole two Ounces of Blood propell'd by the left Ventricle into the Aorta, is drove forwards through its smaller Branches, except only about one Dram that enters the coronary Arteries of the Heart itself.

⁴ The Force of the Arteries propells the Blood even in the Veins till it enters the right Auricle again; but then the Ventricle of the Heart itself is not fill'd with the venal Blood by arterial Force but by the Contraction of the Auricle. To this we may add that the Systole of the Arteries is also in some measure promoted by the Repletion of the small Vessels in their Tunics from the Coronaries, during their Systole.

§. 219. These two Motions of the Artery (§. 217 and 218.) make up what Physicians call the *Pulse*¹, in which they usually consider its *Strength*², *Largeness*³, *Fulness*⁴ or *Tensity*, *Quickness*⁵, and *Equality*⁶, with their Opposites; tho' these are hardly ever observed in any two healthy Persons *alike*⁷.

¹ This, strictly speaking, is only the Diastole of the Artery, since the Finger can only perceive it in that State, being insensible when it contracts into a less Compass from under the Finger.

² The determinate and strong Force with which it repells the Finger in each Diastole.

³ The Difference betwixt the largest Diameter of the Artery in its Diastole, and the smallest Diameter in its Systole; whence, in a healthy Person, a large Pulse denotes a large Quantity of Blood thrown by the Heart into the Aorta.

⁴ A full Pulse is one that feels large in its Diastole, and does not contract much in its Systole; but I make little or no Difference betwixt this and a large Pulse.

⁵ The Frequency of the Pulse is measured by the Number of Dilatations which the Artery makes in a given Time, either in Health or Sickness; but as this is comparative, therefore the chief Physicians to Princes ought to learn the Frequency of their Sovereign's healthy Pulse, that they may judge of its Variation when diseased. In general, healthy Pulses vary according to the Age, Sex, Climate, &c. from 60 to 100 in a Minute; but they are seldom below 70 or above 90, and are mostly about 75 or 80. In Fevers they often run to above 120.

⁶ Equality of Strength, Magnitude, Plenitude, and Number, either separately or conjunctly; which Equality is an exceeding good Sign in all Indispositions, denoting the Return of Health, in which it is a constant Companion.

⁷ As *Bellini* observes. (See also §. 217, N^o 6.) Nor are the Pulses of one and the same healthy Person nearly alike at various times, and under different Circumstances; for there is a wide Difference in their Number and Affections, according as the Person is either in a Passion, sleeping, meditating, exercising, fasting, after Dinner, &c. for as the Resistance of the Arteries varies, so does also their Irritation, and the Force of the Heart, whence arises the Difference of their Vibrations or Pulses.

§. 220. The Blood then, being drove out of the Heart in an oblique Direction against the Sides of the Aorta, strikes and presses on
them

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them in a very *acute*¹ Angle, whereby almost the whole Quantity thrown into it by the Ventricle will be forced against its *Curvature*² or Arch, where meeting with a Resistance from the Figure and Elasticity of the Vessel with the Weight of the preceding Blood, it is thereby *repell'd*³ in all Directions: Hence therefore the Particles of the Blood will every Moment receive a different *Motion*⁴, *Collision*⁵, and *Rotation*⁶; as also a constant *Attrition*⁷, *Attenuation*⁸, and *Compactness*⁹, with an Abrasion or *Levigation*¹⁰ of their Angles; and an Uniformity or *Similitude*¹¹ in each Particle. From all which will arise that *Fluidity*¹², *Heat*¹³, and *Colour*¹⁴ observable in the whole Mass, with that Division of its Parts fitting them *to pass through*¹⁵ all the small Vessels; hence also the Pressure of them into the *lateral Orifices*¹⁶ and Branches to which the Particles of the Blood are convey'd, and the Prevention of them from forming Obstructions in the *Capillaries*¹⁷, all which are still farther promoted by the numerous Anastomoses so frequently observed among the small Arteries, by which the Parts of the Blood meet every Moment with opposite Collisions, Divisions, Commixtures, and Separations in their Course. Nor do we stand in need of any other *Cause*¹⁸ besides this Motion, to account for all the forementioned Effects or Appearances.

¹ The Blood propell'd by the Heart into the Aorta dilates the Sides of it more than of the smaller

Artery ; and as the Contraction of the Artery, is, strictly speaking, successive from the Heart (*per* §. 217, N^o 5.) the Sides of the Aorta at the Heart therefore contract before the rest, though insensibly. But from the converging or conical Figure of the Arteries, the Parts of the Blood do not enter them in Lines parallel to their Sides, but impinge on them in an oblique Direction or in an acute Angle. But when elastic Bodies, like the Blood-globules, strike against elastic Chords, like the component Fibres or Sides of the Arteries, they will be repell'd by the common Law of Reflection, in an Angle equal and contrary to that of their Incidence ; whence the whole globular Mass impinging obliquely against the Sides of the Arteries, will be again reflected with an equal Obliquity against their opposite Sides ; and this Reflection will be continued or repeated from one Side to the other till the Artery terminates. Thus the component Globules of the Blood will receive a perpetual Attrition both against the Sides of the Arteries and against each other ; and by the infinite Ramification of the latter, no Globule will find a Passage into the Veins without having first touch'd in every Point against some Artery ; but in the very last Extremities of the Arteries, which admit only single Globules to pass, by changing their spherical for an oval or oblong Figure, there will be almost a compleat Contract both betwixt the Vessels and Globules, so that no Particle of the Blood will pass without a previous Attrition.

² The Aorta is incurvated soon after its Egress from the Heart, and forms a considerable Arch, against which the Blood is inpell'd from the Heart, and thereby changes its Direction, which was first given it towards the Axis of the Artery ; but even in the smaller Arteries we meet with many
such

such Incurvations, by whose Re-action the Blood will be repelled in various Directions, and the Globules striking against each other will acquire a rotatory Motion, and an Attrition of their Sides, &c.

The Contraction of the Aorta propells the Blood every way, as well towards the Heart, from whence it came, as towards the Extremities; but the three semilunar Valves of the Aorta close so as to prevent any of it from re-entring the left Ventricle, and only two or three Drams enter into the coronary Arteries, which open within the Reach of those Valves, all the Remainder of the Blood expell'd by the Heart being at the same time determined and urged by the Systole of the Aorta towards the Extremities of the smaller Arteries. Now if the Blood flow'd thus through an empty Tube, without Resistances, it would every where run over equal Spaces in equal Times, and continue in the Direction which it first acquired; but the Case being otherwise in the Arteries, the Blood does not move through them uniformly, but with a Direction and Velocity that varies: For the Particles of the Blood, and the Sides of the Arteries being elastic, are subject to that Law of Motion in elastic Bodies, by which, after Collision, they recede from each other in opposite Directions, and with the same Force that they met together. These Collisions will be therefore frequent betwixt the Blood and the Arteries, and more frequent in the smaller than in the larger Arteries; because small Cones have proportionably a greater Surface than large ones: Also by this Collision and different Pressure of the Sides of the compound Globules against the Arteries and against each other, they will be compacted, render'd more solid, and acquire

quire a vortical Motion; which last will both give them a Sphericity and a Polish.

⁴ The Globules of the Blood moving naturally in the Direction of the Axis of their Artery, will be turned out of that Course by striking against its Sides and various Incurvations; so that the impinging Blood will be forced by the Sides of the Arteries towards their Axis, against the succeeding Blood, which will again drive the preceding upon the arterial Sides as before, and in various Directions; by which means no two Globules will continue one Moment together, or in Contact, and being every way compressed, they cannot divide themselves into lesser Globules.

⁵ By which the Nifus or Tendency of all Bodies to move on in a right Line with the same Velocity, is in the Blood-globules continually changed, as well by their various Angles of Incidence and Reflection, as by their different Oscillations and Repercussions among each other.

⁶ Every spherical Body that even moves upon a smooth Plain, will revolve about its own Axis, and describe a Cycloide; whence the Contacts and Attrition of the several Particles in the Blood will be continually changing, and leave no Points or Angles in them unlevigated.

⁷ The Blood-globules are compressible, and have an expanding Force, by which they act on each other, and on the Sides of the Arteries, especially in the very minute and elastic Capillaries through which they are forced with so great a Velocity; and hence it is the Heat of the Blood arises. (*Vid.* §. 229.)

⁸ By the Division of the larger Globules into less as they strike against the Angles of the ramifying Arteries.

⁹ Their Density or Compactness will arise from the Union of several small Globules into a larger one,

one, which will retain the Weight of all the six united Spherules under a less Surface; and it is a Diminution of the Surface without removing any of the Weight that increases the Density or specific Gravity of Bodies. To this add the Abrasion of angular Parts, and the closer Approximation of the rest by a constant and equilateral Pressure; by all which means the Particles of the Chyle and Milk, in themselves lighter than Water, are converted into Blood, which is a twelfth Part heavier than Water, even tho' it be extravasated, for I suppose it was more compact in the Vessels as it is there compressed, but expands in the Air, as we may conclude from the Diffillation of the Globules, or the Cruor's turning into Serum by standing.

10 A Sphere moving among other Bodies meets with an equal Resistance in all the Points of its Surface, in which if there are any Angles or Inequalities more remote than other Parts from the Centre, the Resistance or Attrition will be the strongest upon them, so as to abrade and grind them off; whence the Sphere will be compleated and move freely in every Point. By these means every nutritious Particle of our Chyle, assumes a globular Form, except the excrementitious, earthy and saline Parts, especially those of common Salt, which *Lewenboec* has observed floating in the Serum of the Blood; for so retentive are the Particles of that Salt of their natural Cuboide Figure, that after they have passed the Circulation, and been putrified in the Urine for three whole Years, they receive not the least Change. *Vid.* my Chemistry, Book II. Process 101.

11 This homogeneous or uniform Texture of the several Parts of the Blood, being that of Spherules, varying only in Size, arises from their Attrition
among

among each other, whereby the angular Parts are abraded ; for while the alimantal Particles in the Blood continue rough and unequal they are rather offensive than nutritious, and are not properly Parts of the Blood. Hence you may resolve the great Question how all sorts of People feeding on different Aliments make the same Blood from each ; for this Change seems to arise chiefly from the Lungs (§. 200, N° 11.) and Arteries, compacting and levigating the smaller Spherules of our alimantal Juices (§. 127.) into the larger Globules of Blood and Lymph, agreeing in Weight, Solidity, and Colour ; including also the Action of our indigenous and chylicative Juices (§. 126, N° 6.)

¹² There is some Difficulty in accounting for the Blood's Fluidity in the Vessels, when it even congeals in them, and becomes a solid Mass barely for want of Motion ; but neither its Heat nor progressive Motion in the Veins are sufficient for this (considering the Viscidity and cohesive Nature of its Parts) without the Interposition of a certain Portion of the universal Menstruum Water, and an intestine or rotatory Motion in each Particle preventing their Combination with each other, to which add the Efficacy of the Lungs (§. 200.) The Ancients indeed imputed this Fluidity of the Blood to a Ferment, when they needed nothing more to account for it than the conical Figure and Action of the Arteries, with a sufficient degree of Motion in the Blood communicated from the Heart ; for otherwise, the Blood not only congeals after Extravasation, but even in the Vessels poly-pous Concretions are sometimes formed in a Syncope in less than one Minute's time.

¹³ The Heat of the Blood arises in an eminent degree from the elastic Vibrations or Contractions of

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of the Arteries, since a Man whose Blood is almost frozen will recover his Heat barely by Exercise or muscular Motion. The Heat of the Blood then in the human Body is proportionable to its Velocity and Number of the red or largest Series of Globules it contains ; the Intensity and Variation of which Heat may be most commodiously estimated by the mercurial Thermometer of *Farenheit* of *Amsterdam*. If the Bulb of this Instrument be inserted into a Patient's Mouth, after you have marked the Degree of the Atmosphere, and the Patient shuts his Mouth, breathing only through his Nose, the Ascent of it will then indicate how much he is hotter than the Air ; which freezes at 32 *gr.* is cold at 40, temperate at 50, warm at 65, and sultry (at which Butter oils) at above 80, tho' 'tis tolerable for some Hours in a Bagnio at above 90, equal to the usual Heat of the Sun at Noon in the Dog-days, and from 96 to 100 is the healthy Heat of human Bodies, which in Fevers ascends to 110, and even Water scalds a soft Hand when heated to 112 or 114 ; the White of Eggs, Serum and Lymph harden at about 155 ; Alcohol boils at 175, and Brandy (which is half Water) at 190, Spring-water at 212.—Hence as there is so little Difference betwixt scalding Water and the Heat of the Blood in ardent Fevers, no wonder that they so soon evaporate the aqueous Parts, and inspissate the rest of the Blood, and then induce a putrid Thinness ; or that they are often not tolerable above three Days, and by that time the soft Brain is in a manner, parboiled or scalded ; and the Texture of the Blood is often so dissolved that a Dropsy attends the Patient after his Recovery from the Fever, caused by a Dissolution of the larger red Globules into lesser serous ones. If the Motion and Heat of the Blood decrease, it becomes serous
or

or watery, and a Cachexy follows. But some will say, that the Heat of the Blood is not always as the Quickness of the Pulse; this I allow, for the Pulse may be very quick and the Blood at the same time move slow, as in a Person that is dying.

^{14.} We are assured that no other Causes are required to make the Blood red than the Action of the Lungs and of the Arteries, by which the largest Globules not only assume that Colour but are also formed equally large, dense, smooth, and spherical; for when the Force of the Arteries is diminished, the Blood soon loses of its red Colour. If a Man in perfect Health is any way weakened, and his Circulation, or the Heat and Attrition of his Blood thereby diminished, he will in a little time look pale, and his Blood will become ferous or discoloured. Girls, at the first Appearance of their Menfes, often lose their Colour, look pale, and have a Weakness in their Limbs and Coldness all over their Body; their whole Skin also turns of a pale, greenish, or yellowish Hue: And their Blood, upon Examination, has very little Redness in it, but appears watery, and like the Washings of Flesh, which is also the State of the Blood after Intermittents, and many chronical Disorders. But such a Girl, by various Exercises with Chalybeats and Corroborants, which increase the Velocity, Attrition, and Heat of the Blood, will recover her former Health and Beauty. We therefore need not call in any Effervescence of an acid Chyle with the Blood to account for its Redness, nor any Mixture made in Vacuo, nor the Action of any alkaline Salt, as that of the Sal Tartari boil'd with Milk.

¹⁵ To render the Parts of the Blood pervious to all the Vessels, it required to be stock'd with Globules

bules of various Sizes, corresponding to the Orifices of the several Series of Vessels ; but this is effected by the Division of the larger Globules into those of lesser Orders by the Action of the Lungs (§. 200.) or pulmonary Arteries ; and that the larger Globules will thus dissolve into less, is proved to the Eye by the Microscope, when the Cruor has enter'd a Vessel too small for its Passage.

¹⁶ When small Branches go off from a converging Vessel or Artery, towards its Apex, having Orifices too small to admit the red Part of the Blood, I say that in these lateral Orifices will enter all those fluid Particles which are either of an equal or less Dimensions ; while the more gross Particles, by whose Weight and Pressure the more subtile were forced into the lateral Orifices, go on still towards the Apex of the Cone or Vessel : Hence, the smaller and fewer the lateral Branches or Orifices, the more of the Juices will continue moving forward in the arterial Trunk.

¹⁷ The Blood would be in imminent Danger of stagnating and concerting in the Extremities of the small Arteries, (where its Motion is slowest, its Resistance greatest, (§. 215.) its Heat the least, and its diluent or thinner Juices in the smallest Quantity) if it were not highly attenuated by the arterial Plexus's spread through the Lungs (§. 198.) and Muscles ; in which, by their frequent *Anastomoses* with each other, like the Marshes of a Net or a Spider's Web, every individual Particle of the Blood is propell'd in various and contrary Directions. If any Obstructions are formed, by these Inosculation, the obstructed Capillaries are also prevented from being either totally block'd up or burst, by the Impulse of the succeeding Blood, which will take its Course freely through the next communicating Branch, till the obstructing Matter

ter be either attenuated and dissolved, or else protruded through or removed by the frequent Shocks of the Artery. When one has got a Cold, with a Defluxion on the Fauces and Parts adjacent, there are then an infinite Number of small Arteries obstructed which deny a free Passage to the Blood; but all this is quickly dispersed and removed by a Day's fasting, and plentiful drinking of warm diluent Liquors; for thus the obstructive Matter will be attenuated or removed, and Arteriolæ become pervious as before. And *Lewenboec* has often seen the Particles obstructing a capillary Artery dissolve either by an Increase of Warmth, the repeated Shock of the Arteriola, or by its returning towards the wider Part of the Artery.

¹⁸ That is the Cause of any thing by removing which the Effect ceases; but we are assured, by Experience, that the Fluidity, Heat, and red Colour of the Blood are always more intense when the Arteries and Lungs are strong, and act on the Blood with sufficient Force; and that they are more faint or remiss when the Strength of the Arteries and the Blood's Attrition by them is diminished. 'Tis both needless and useless to enter into a Detail of the various Causes assigned by different Authors for those Appearances of the Blood, since they all appear to be fictitious except that here given. Thus a Man lately drowned is deprived of the Heat, Fluidity, and other Affections of the circulating Blood, notwithstanding all the supposed Ferments, Salts, Sulphurs, Oils, &c. are still within the Mass, and nothing is wanting but the Motion formerly given it by the Heart and Arteries, which must be the Cause enquired after.

§. 221. For if the Blood retains all its Parts and Affections, except the Motion given to it by

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by the Heart and Arteries, it quickly *congeals*¹, and becomes more a solid than a fluid Mass; but whilst actuated by the Causes (at §. 220.) it continues to be a Liquor adapted to all the Offices of Life.

¹ The Blood, consisting of Globules of various Sizes, which only retain their Sphericity while moving fast enough in the Vessels, is no sooner extravasated, but by pressing on each other, and by the Force of Attraction they will become little flat Cakes, whereby their Surface being increased, and consequently their Cohesion, they will form a continuous or solid Mass; but this Attraction and Cohesion will be greatest in the smallest of the compressed Globules, as they will have proportionally the largest Surface and Contact; these will therefore cohere to each other so strongly, by the Help of an intermediate Gluten, as to form elastic Chains or Threads. From hence you may understand the Formation of polypous Concretions, whether made in the Vessels, or of extravasated Blood by Art. The Blood is therefore a Liquor composed of Parts naturally apt to cohere and become solid, if not prevented by a due Degree of Motion; which is a very necessary Affection of it so far as it is a nutritious Fluid.

§. 222. But as the Arteries gradually increase both in Number and *Capacity*¹, being in some Places narrower and in others broader, they will, in every Part, continually *deposite*² or lose some of their Contents, which never return again; but as the Resistances are also greater, or even greatest in the smallest
M Arteries,

Arteries, and much of the Blood's Impulse is there impress'd and lost upon the *ambient Parts* ³, therefore the Motion of the circulating Juices will be, *cæteris paribus*, *swiftest* ⁴ near the Heart, and slowest in the most distant Parts or Extremities.

¹ We before observed (§. 215.) that the Aggregate or Sum of the Diameters of the small Arteries greatly exceeds that of the Aorta; which we have the less Reason to doubt of, as we find the Lights or Sections of the first Division of the Aorta (into the Subclavians, Carotids, and descending Trunks) to exceed the Section of the Aorta itself at the Heart, nearly as 3 to 4, or 5 to 6; which Difference will be still immensely greater as the Arteries are farther ramified; so that the Blood moves on continually in the Arteries from a small Capacity to a larger, and will therefore lose proportionably of its Velocity, as it goes farther from the Heart, till it is almost quite lost at their Extremities opening into the Veins: But *Ruyfch* and *Lewenboec* demonstrate that the whole Skin under the Cuticle is so full of exhaling Vessels, that one cannot enter the smallest Needle without wounding some of the Arteriolæ; so that almost the whole Surface of the Body may be taken as the Area or Section of the exhaling and cutaneous Arteriolæ only in Comparison with a Section of the Aorta; but how prodigiously will that be augmented by adding the Sections of all the Arteriolæ of the Muscles, Viscera, Bones, &c.

² Such as all the secreted Juices, Lymph, nervous Juice, the Matter of Urine and Perspiration, (which last amounts to five Pounds a Day in *Italy*, according to *Sanctorius*) the Saliva, Tears, &c.

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℄c. all which are more fluid than the Blood itself from whence they are separated, and are either discharged out of the Body, or at least do not return into the Arteries again: Whence it follows, that the Blood having parted with all those more fluid Juices in its Passage to the Extremities of the Arteries, it will be there less fluxile, and will move slower.

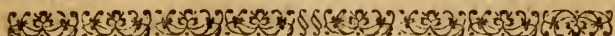
³ A Body moving in a perfect Vacuum, would go on with the same Velocity for ever, and in a right Line; because it would not then meet with any other Bodies to change its Direction, nor resist its Motion: But if this Body strikes upon others in its Course, it will communicate Part of its Motion to each of them till it has lost all its own; whence a Stone that has been flung into the Air goes on in a right Line till it has given so much of its Motion to the resisting Medium, that the Force of Gravity becomes more than equal to its remaining Impulse, whereupon it falls to the Earth. In the same manner the Blood communicates its Impulse to the Arteries, and these again lose Part of their Motion in removing the ambient and resisting Parts, such as the Fat, Muscles, Skin, Atmosphere, &c. (§. 215. N^o 5, 7.) which being soft Bodies do not return the Force like rigid and elastic ones; for if two Balls of soft Clay be suspended by Strings, and impell'd against each other in contrary Directions, all their Motion is destroy'd, and ceases at the Points of Contact; but if they are first hardened and baked, so as to become rigid and elastic, they will then recede from each other after Contact with a Force equal to that with which they met. In this manner a great Part of the Blood's Motion is lost upon the circumjacent Parts, and especially upon the Fat in People of a corpulent Habit; in which last Part

therefore the Blood sooner stagnates and obstructs the small Arteries than in others.

4 The Difference of the Blood's Velocity in the Aorta and capillary Arteries, is computed by Dr. Keill to be at 44,507, to 1. But this Velocity and Motion is both the swiftest and the least impaired in the Arteries of the Heart itself; for in these the whole Quantity received, in each Diastole of the Heart, is forcibly propell'd and discharged by the next Systole of this Muscle; so that it circulates through the coronary Arteries in the 3600th Part of an Hour (*per* §. 184.). Next to the Vessels of the Heart, the Blood moves swiftest through those of the Lungs, in which it is accelerated by their Action or Respiration, (*per* §. 300 and 308.) and next to these it moves quickest thro' the Inter-costals and Phrenics, in which its Course or Circulation seems to be compleated at every Respiration. Nor does the Blood move with the same Velocity through the other Parts, but in some slower than in others; slowest in the Arteriolæ of Adeps and Medulla, in which the Motion is scarce sensible: But the Blood does not always move in Proportion to its Distance from the Heart, for different Circumstances may make it move an hundred times quicker in some than in others; and strictly speaking, its Velocity varies in every Vessel, in Proportion to its Section and Angle at the Trunk, its Complications, and other particular Affections unobserved. Thus the carotid Arteries before they reach the Cranium have their Coats dense and compact; but upon entring the Cranium, they deposite their thick muscular Tunic, and become thin as Veins, and larger than before; by which Mechanism the Blood flows into them in a greater Quantity, as they have less Resistance, and moves slower through them as they have a less contractile Force.

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Force. Much the same Mechanism is also observable in the arterial Branch that conveys Blood to the whole spinal Medulla down to the Coccyx, which arising from the Conjunction of the two vertebral Arteries at the *Medulla Oblongata*, the Blood takes a retrograde and slow Course thro' it. *Vid.* §. 231 and 232.



Of the Nature, Composition, and Qualities of the Blood.

§. 223. **B**UT in the several Constituent Parts of the Blood itself, is also concealed a great deal of the Cause both of its *different*¹ Course and Velocity in the Vessels; for that it is compounded of various and distinct Particles, we are assured from the Matter of its Composition; from its spontaneous Separation, when at rest and out of the Vessels, into a *vapoury*², serous, and fibrous Substance; and lastly, from the Principles it affords by a chemical *Analysis*³.

¹ The Blood is a warm, red, and seemingly uniform Liquor, circulating through the Heart and Vessels of living Animals. If its Parts were perfectly hard and similar, meeting with no Resistances they would go on in strait Lines. And Mechanics teach us, without any Falacy, that, by the Experiments of *Hugens*, if an hundred Ivory Balls are placed upon a smooth Table, by giving

an Impulse to the first, the rest will stand still, and impart all their Motion to the last, which will depart with the same Force and Velocity that the first was impell'd with against the rest, and would continue moving in the same Direction, and with the same Force, if it were not for the Resistance of ambient Bodies. If a Bullet and a Feather are dropt at the same Instant from a certain Height in the open Air, the Bullet will be down first, and leave the Feather floating behind; but if a Feather and a Guinea are dropt at the same Instant from an equal Height in an exhausted Receiver, they then both arrive at the Bottom in the same Instant of Time, all Resistance being there removed. It therefore follows, that a moving Body loses of its Force by the Impulse which its Surface gives to the ambient and resisting Corpuscles, and that therefore the Body will be resisted in Proportion to the Largeness of its Surface; but when several different Bodies are projected forwards with the same Velocity, their Impulse on others will be also, in Proportion to their Density or Quantity of Matter under a given Surface. Hence we learn, that in the Particles of the Blood moving all by the same Force of the Heart, those will pass on the swiftest and the nearest to a right Line which have the least Surface and the greatest Weight; or to speak mathematically, the Velocity of each Globule will be in a Ratio directly as the Density, and inversely as the Surface. So that if the Globule A be double the Weight of B, it will go over double the Space by the same Impulse in the first Instant, and in the second Instant it will have out-gone B twice as far as it did in the first Instant of Time; whence their Distance from each other will perpetually increase, as the times — Another Difference in the Motion, arising from their greater Density and

and Sphericity, is that they will move longer, and be more retentive of their first Direction in a right Line. If several lesser Globules unite into one larger, without losing any of their Matter, they will become more dense, or acquire a less Surface; but if one large Globule dissolves into several less they will acquire a greater Surface, if no Change be made in the Texture of their Pores and Particles.

² Being that ill-smelling Vapour which exhales from Blood just extravasated, of which we spoke at §. 167. But the fibrous Parts are no more than Chains of Globules attracting and adhering to each other (*per* §. 221.)

³ Let some Blood of a healthy Person run into a clean Glass Body, to which adapt a Head, and place them in Balneo with a Heat not exceeding that of a healthy Body, *viz.* 100 gr. you will then have Vapours ascend and condense into an insipid Water, having little or no Smell, and in nothing differing from common Water, only in having some of the foetid Odour observed in the killing or opening of all Animals; nor can we discover any acid or alkaline Salt therein by any Experiment. In the next place let the Cake of Cruor, and the remaining Serum in the Body, be urged with a stronger Heat of 214 gr. equal to that of boiling Water, and thus you may from a Pound of Blood draw off near ten Ounces of Water, till the remaining Mass is almost dry, which will not then putrify by standing. From this Experiment we learn, that there is not naturally any volatile Salt in the Blood, since none ascends from it by so strong a Heat as that of boiling Water. But if you now urge the remaining Mass with a greater Heat of 300 gr. you will first obtain a volatile Salt, with a yellow Oil, then a foetid or empyreu-

matic Oil, and lastly a very heavy and thick Oil, leaving a black Mass, like a Coal, remaining in the Bottom of the Vessel. But you must know that these are not the natural but factitious Principles of the Blood, produced or made by the Intensity of Fire. It is therefore an Error to suppose that the saline Parts of the Blood are naturally acrid and volatile, since the Water first distill'd from it will keep many Years without yielding any urinous or acrid Smell and Taste.

§. 224. There are therefore in the Blood (1.) some Parts already in Motion, and which have a great Disposition to move by the least Impulse, from their *Solidity* ¹, Smoothness and *Sphericity* ², there are also (2.) others *sluggish* ³, or unapt to move by a small Impulse, as being *porous* ⁴, *angular* ⁵, rough or *viscid* ⁶: Hence we know, by the Laws of Mechanics, Hydrostatics and Hydraulics, that these Particles of the Blood, though propell'd by the same common Force of the Heart, will not all move on with the same Velocity, Direction, and Continuance: For the Course of the first will be swifter, longer, and more nearly in a *right Line* ⁷ from the Heart; while the latter move through the Vessels more slowly, obliquely, and backwards or towards the Sides.

¹ Having the greatest Cohesion of Parts, with the fewest Pores or the smallest Surface; by which they will be more retentive of their Motion, and meet with less Resistance, *i. e.* they will be more fluid: Whereas the more light and porous Parts

will

will be less susceptible and retentive of Motion ; *i. e.* they will be more viscid or less Fluid, notwithstanding their Particles being smaller than the former.

² Great are the Advantages of this Figure for Fluidity and Motion in Bodies ; for it contains the most Matter under the least Surface, has every where an equal Resistance, and comes into Contact with other Bodies only in single Points : No wonder therefore that Spheres should assume the most Motion from the same or a common Impulse, or retain their Motion longer, and their Direction more strongly than Bodies of other Shapes.

³ Such as are less easily put into Motion, and the sooner lose it ; from their Roughness, Lightness, and their Attraction or Tendency towards other Particles, &c.

⁴ If two Atoms are conjoined into a Body, with an intermediate Space betwixt them, that Space will be a Pore, and the two Atoms will separate with the utmost Ease by a Force acting upon them in that Point ; and from this Pore it will have a less Power on other Bodies, since Space has no Action : But if that Body be again dissolved into two Atoms, each of them will become more solid and retentive of Motion, as having no Pore or empty Space ; for Matter only is susceptible and retentive of Motion, and therefore in Bodies of the same Bulk, those are least porous which have the greatest Weight, *e. g.* Oil and Fat weigh less than Water, and therefore they are more porous.

⁵ If a little Drop of the Blood's Serum be taken up in a capillary Glass Tube, in a warm Place, and then view'd against the Light with a Microscope, it exhibits, besides Globules, a great many angular or sharp-pointed Particles, and Spiculæ of a saline Nature, which seem to be rather Stimuli

to the Vessels than necessary or constituent Parts of the Blood.

⁶ Such as strongly attract and cohere to themselves and to other Corpuscles, and which therefore cannot be of a round Figure, because they touch and cohere by large Surfaces and not in single Points, and Cohesion we know is as the Surface in Contact.

⁷ Every Body in Motion endeavours to go on in a right Line, if its Direction is not alter'd by some other Force or Resistance; and this *nifus in directum* will be greater as the moving Body is denser: So that in an Assembly of Particles of various specific Gravities moving by one common Impulse, the heaviest will keep on their Course the nearest to a right Line, while the less heavy recede laterally or obliquely from their first Direction. Thus for Example, if you discharge a Spherule of Gold, another of Cork, and another of a Piece of Bladder fill'd with Air, and placed in that Order in a Wind-gun; the Spherule of Gold will then go forwards in a right Line, and drive away the other two laterally in Lines of Obliquity proportionable to the Gravity of each. And the same it is with the component Globules and Particles of the Blood projected by the Force of the Heart along the Arteries, in which the more dense and spherical Particles will tend most in a right Line, or towards the Axis of the Vessel; while the more viscid, rough, and porous Particles will be forced towards the Sides and drove into the lateral Orifices. In the same manner we observe in Rivulets and Currents of Water, that the lighter Soil is forced to the Sides and sticks to the Shore, while the more heavy is drove with a greater Velocity along the middle of the Current. Hence we learn, that in the Course of the Blood thro'

thro' the Arteries, it does not continue equably mix'd as it was in the Heart, but that various Sorts of its more light and dissimilar Particles are thrown towards the Sides, and into the small lateral Orifices of those Vessels according to the Blood's different Velocity in each; while the more compact and similar Particles, the red Globules, continue on their Course to the Veins along the Axis of the Artery; and this it is that makes the first Preparation of the Blood in order to the various Secretions. To confirm what has been said, if you drive a Mixture of small Shot and round Bits of Wood along a ramified Tube, the wooden Spherules will run into the lateral Branches while the leaden Shot continue on in the Trunk.

§. 225. If it be asked why the venal Blood in a dead Body is found to retain its Fluidity a long *while* without congealing; when at the same time that in the Heart and Arteries is quickly concreted; we answer that it is probably owing to the more fluid Parts being continually pressed and discharged into the Veins, while the Arteries in the mean while continually lose all their more fluid Juices, and receive no fresh Supplies.

* In opening dead Subjects the Blood is usually observed uniformly mix'd and fluid in the Veins, even on the third Day; but in the Arteries we find little or no Blood but what is concreted and like a Polypus. The Reason of which is, that the Cold contracts all the Fibres and small Vessels, and the Arteries being much stronger than the less resisting Veins, do continually protrude the most fluid Parts of their contained Juices into the last mention'd

tion'd Vessels, while the thicker Parts of the Blood remaining in them concretes ; thus the most fluid Parts of the Blood will reside in the Veins and the grosser in the Arteries, so there continues to be a sort of Motion and Separation in the Blood even a long Time after Death.

§. 226. But though the Blood in a living Body seems to be equally red in every Part of it, yet if it be view'd through a *Microscope* ¹ it consists of red Globules swimming in a thinner and almost pellucid Serum, so that every red Globule is made up of six smaller, which when separated from each other are pellucid and yellowish, putting on the Nature of Serum, which appears of various Colours. From whence arises the *Substance* ², *Figure* ³, Size, and different Colour of these Particles, is apparent from what we have before delivered ; but it is not so easy to know how far this *Division* ⁴, of the larger into lesser Globules, is extended ; we are however acquainted with the Uses or Effects of the *larger* ⁵ red Globules, and of the serous ones, and also know why the former are so *necessary* ⁶ in the Blood of a strong healthy Person. In effect, those Particles which we call cruor or red Blood, are the largest or grossest of all the Homours that have their Birth and Inhabitation either in the Arteries, Veins, or any of the Viscera of a Person in Health ; the next that follow in Size, are those of the yellowish Serum, which hardens with Heat ; next come the colourless lymphatic

lymphatic Juices, which also congeal with Heat; then the limpid Humours not concreting by Heat with the Milk, Urine, and all others gradually decreasing in the Size of their Particles, but not yet accurately classed or enumerated 7.

¹ The Texture of the Blood observed formerly by *Lewenboec* has been since universally received among the Learned; and I have myself frequently confirmed the Truth of it by an infinite Number of Experiments. A little of the Blood that comes out of a Puncture in one's Finger, being first diluted with a Drop of Water to make it more pellucid, then taken up in a capillary Glass Tube and applied to a Microscope, appears at the first View to be all red, but afterwards you may distinguish the red Globules in its Composition, swimming in the almost pellucid and aqueous Serum. These red Globules lose that Colour by standing still, even during your Observation; so that after a while you can perceive none but yellow Globules instead of the red ones, six of which yellow ones are equal to one of the red: *Lewenboec* has not only often seen this Separation of the red Globules into the lesser serous ones, but he has also seen the Combination of the serous ones together, by sixes, into the larger red ones, in Fish and Insects. But upon repeating your Observation after a longer Interval, you will perceive that all the yellow Globules are vanish'd, and that there now only remains pellucid and smaller Spherules, each six times less than the yellow or serous Globules, and thirty six times smaller than the red ones. Here the Eye is incapable of descending any farther into smaller Divisions of these last Globules, but by Reason

Reason and Analogy we have some Foundation to believe that the more subtle Juices in the human Body are composed of still smaller Globules, and that there are as many Series of decreasing Globules as there are of the smaller Vessels conveying the several Juices; and *Lewenhoec* affirms, he has seen some Vessels in the Brain of 512 times less Diameter than the red Globules. We observe then that the largest Particles in the Blood are the red Globules, composed each of six yellow or serous ones; and if ever there were any larger than these, they are not healthy but morbid, and formed by the Cohesion of several red Globules together, as is observable in many acute Fevers. The Size or Magnitude of each red Globule is determined by the Diameter of the smallest sanguiferous Arteries in the Lungs; as it is also probable the Sizes of the smaller serous ones are by the several Orders of lymphatic Arteries in the same Viscus. When the larger red Globules passing through the Arteries are presented to Orifices of their lateral Branches too small to admit them, they then keep on their Course in the same Vessel towards the sanguiferous Vein into which it opens; while the smaller yellow and serous Globules enter into and pass along the small lateral Branches whose Orifices were impervious to the red ones. Again, when these serous Globules arrive at Orifices too small for their Admittance in passing through their proper Artery, they will go on into their corresponding serous Vein, while the smaller, pellucid, and colourless lymphatic Globules will run off through the smaller Arteriolæ, whose Orifices refused the larger yellow or serous Globules; and in the same manner will the Course be carried on in their Passage through the lymphatic Arteries of the several Orders into their corresponding Veins.

² It is remarkable, that in most of the Substances we use as Aliment there are large Globules discernable, of a lax Texture, and of different Sizes; which in the Chyle become less and more compact, or denser and smother; and which in the Blood are again formed into still more compact and larger Globules. *Vid.* §. 127.

³ From the Figure of the smallest Vessels in the Lungs and Muscles through which they are forcibly strained, and from their equable Rotation and Attrition among the other similar Spherules of the Blood itself.

⁴ The red Fluid we call Blood, which is the thickest or grossest of any circulating in the human Body, contains the Materials of all the other Juices found in every Part of the Body; for the Serum comes from hence, in which is comprised all the other Juices of the Body, except the Blood itself; and by dividing successively into lesser Particles it supplies all the Series of Vessels, even to the most subtile Juice or Spirit of the Nerves. But the Serum is composed of Particles of different Magnitudes, whence the Milk passes through Vessels which the Serum will not, since we do not observe the hardening Serum in the Milk. The same may be said of the Saliva, Urine, &c.

⁵ The Stability or Permanence and Strength of the Body depends on the Blood and thicker Juices, which receive and impress the Force of the Heart upon the other finer Juices in the smaller Vessels; thus the Blood moves or propells all the thinner Juices of the Body without entering into their smaller Vessels itself; and in this manner one Series of Globules will protrude the next through the several Orders of Vessels, and that too with a lesser Force proportionable to the greater Thinness of their Coats or Sides, by which they will
avoid

avoid Rupture. And thus too, one Humour will digest and prepare the next, throughout the several Series of Vessels, from the thick Blood down to the subtile nervous Juice, or from the Time of their Ingestion till they are consumed and expell'd in Form of an invisible Vapour, after having performed all the Offices in the Body. For Example, in the White of an Egg, we are assured that from thence are formed all the different, solid, and fluid Parts of the Chick within the Space of three Weeks ; and there is little or no Difference betwixt the Serum of the Blood and the White of an Egg : So that we may hence easily conceive the Serum sufficient to supply all the several Juices of the Body, and differing in Texture or Fluidity, not excepting even those which are volatile, and fly off into the Air. But this Change, either in the Serum or Albumen, is not made all at once but by a slow and gradual Attenuation, by which it is at last subtilised into the most fluid Juices of the minute and tender Chick. In the same manner we apprehend that the Serum is successively attenuated and subtilised as it passes through all the several Orders of the ferous Vessels, whose Number we are unable to determine, till at length it is fit to nourish and pervade the minutest Recesses of the Body ; and perhaps this Change too of the Serum may be made in the like Space of three Weeks or twenty one Days ; since the Serum and Albumen are so much alike in Substance, the Heat of the human Body but little less than that of a sitting Hen, and the different Juices thence made in the Chick, the same with those made in the human Species, Lymph, Bile, &c. 'Tis even a Question, whether the Menfes in Women do not arise from this Quarter, since they generally become plethoric in the like Space of about twenty one Days,

Days, on which see more at §. 659, following. But was this great Attenuation of the Juices, from their Ingestion to their Exhalation, to be made suddenly, or in a short time, the whole Body would be quickly lost insensibly in Vapours; to prevent this therefore, the wise Architect has framed our Blood and Serum, with a certain necessary Degree of Firmness, and order'd it to pass through several Series (the Number of which we know not) of minute Vessels, each smaller than the other. Lastly, it is from the largest sized, or red Particles of the Blood that its Heat arises (*per* §. 220, N^o 13.) for the other Juices in its Composition, notwithstanding their Motion, do not generate Heat; so that those Parts of the Body are coldest where the red or sanguiferous Arteries are fewest, as in the Substance of the Brain, &c.

⁶ For the Vibrations and Concussions of these spherical Machines are almost as necessary for digesting and farther attenuating the Chyle as those of the elastic Fibres and Arteries themselves; so that when the Blood is once impoverish'd or become too serous, it is then over with the necessary Digestion of the Chyle in the Blood previous to all the other Functions; or as *Hippocrates* says, "When our Aliments are too tough or strong, they breed Diseases; when too weak or lax, they will not sustain their Office."

§. 227. From what we have before delivered you may easily conclude what Judgment one ought to form concerning the *Galenical*¹ and *Chemical*² Doctrine advanced to explain the Nature of the Blood.

¹ *Galen* and his Followers gave the Name of Blood to all that red Liquor contained in the Arteries

teries and Veins, which they distinguished into four Sorts of Particles or Humours: Blood, more strictly so called, as giving the red Colour to the whole Mass; yellow Bile, or the Serum in which the Crassamentum swims; Phlegm, or the pellucid Liquor into which the yellow Bile or Serum changes by standing; and lastly, the Atrabilis lying at the Bottom of the Vessel, being only the heaviest and darkest Part of the Crassamentum. From a Mixture of these four Humours in due Proportion, say they, arises the most healthy Constitution of the Body; but when any of them are predominant above the rest, they will occasion some of the Temperaments of §. 228.— But from the preceding microscopical Observations of *Lewenboec*, it readily appears, that the Crassamentum is nothing more than an Assemblage of Globules cohering in one Mass; and that the yellow Bile is only the Serum without any Bitterness, since there is never any Bile observed in healthy Blood, for if any be found there it is morbid and occasions a Jaundice. Their Phlegm too is no more than the Serum whose yellow Globules are dissolved into lesser pellucid ones by standing; but their Atrabilis is truly a Part of the Crassamentum, or the largest and heaviest, or the most compact of the red Globules, which therefore sink lower than the rest and appear of a darker Colour.

² The noted *Basil Valentine*, of whom we can only learn that he was a *Benedictine* Monk in the Monastery of *Erford*, (though we are much indebted to him for his early Dissertations in Chemistry, and know that he must have lived after *J. B. Carpenfis*, because he directs to cure the venereal Disease with Mercury) was the first who taught that the Blood consisted of Salt, Sulphur, and Mercury; in which Doctrine he was followed by

Paracelsus

Paracelsus and many others. By the Mercury they understood the volatile and aqueous Parts of the Blood, and by Sulphur, its oily Parts ; taking no Notice of its earthy Parts, which are very different from the saline, and plentifully contained in the Blood, as we know from its being used in the making of Tests for refining Metals. There are other Chemists again who teach us that those are the genuine Principles of the Blood which it affords by an intense Fire ; viz. Oil, a volatile alkaline Salt, Water, and Earth. Thus if recent Blood be exposed in a Retort to a Heat of 100 gr. in *Balneo Mariæ*, there comes over first an insipid Water, almost to half the Quantity with the Blood ; then with a stronger Heat comes over more Water impregnated with Oil a little, and a foetid Smell ; and by increasing your Heat above 276 gr. you obtain a strong and pungent Liquor or Spirit compounded of a volatile alkaline Salt, Oil, and Phlegm ; after that a volatile alkaline Salt arises in a dry Form, follow'd with an empyreumatic yellow Oil ; and last of all, your strongest Heat raises a more ponderous and thick Oil than the preceding (which if obstructed in its Passage through the Neck of the Retort by Cold or otherwise, it never fails to burst the Vessels) leaving a black dusty Substance like a Coal in the Bottom of the Retort. But all these acrid Salts and Oils are the Produce of the Fire, and not the natural Principles of the Blood ; for if such were contained in the circulating Juices of our tender Vessels we should be soon destroyed, or our Vessels dissolved, even before our Birth : And besides, if you return and mix them all together again into one Mass, they form a Compost in every respect foreign and dissimilar to the Blood ; and therefore this is not the way to acquire a just Knowledge of the natural Elements or constituent

Principles of this animal Fluid. As these Principles are unjust, the Explication of the Blood's Nature derived from them will be equally groundless; for its red Colour is not caused by any Sulphur, but a Condensation or Combination of the Globules. If you nourish a cachetic Girl even with an Egg Diet, she will not improve the florid Colour of her Blood; but if you only feed her with mere Bread and Water, and add repeated Exercise to it, she will both recover the Redness of her Blood and the fresh Colour of her Cheeks.

§. 228. And from what has been advanced too, you may perhaps discern that the various Conditions of the Blood in different People, and the usual *Temperaments*¹ thence deduced, are much better derived from its component aqueous, oily, saline, and earthy *Parts*².

¹ The Ancients reckoned as many Temperaments as Humours; viz. phlegmatic, choleric, melancholic, and sanguine, with their Subdivisions or Combinations, resulting from two or more of their Humours being predominant in the Blood (*per.* §. 227, N^o 1.); but if their Doctrines ought to be rejected, the chemical ones deserve to be much more so.

² Water so much abounds in all our Blood and Juices, that it is doubtless the chief Principle or Element throughout the whole Body; and even the Solids themselves are derived from the Fluids, and afford an extraordinary Quantity of Water by various Experiments. Earth makes the Basis or least and rigid Particles of the Solids; and Oil manifests itself abundantly in the Fat or cellular Membrane, as well as in the Blood by the Microscope: And
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that there are Salts in the Blood appears too not only from the Microscope (*per* §. 224, N^o 5.) but also from the acrid and deterfive Quality of the Bile (§. 99, N^o 2.) and Saliva (§. 66, N^o 9.) &c. But though the human Salts are alcalescent, they are not naturally alkaline, but come nearest to Sal Ammoniacum; and whatever Principles we observe in any of the Juices they must have been first in the Blood, as all the Juices are thence derived. Hence then we conclude, that there are Particles of Water, Earth, Salt, and Oil circulating in the red Blood through the small Vessels of our Bodies; the different Quantities and Qualities of which will equally account for all the Appearances attributed by the Ancients to their several Humours and Temperaments. When Water is redundant it will produce Relaxation, dropfical Tumours, Coldness, Paleness, and Weakness; when Salts abound, the Juices will be too acrid, stimulating and eroding, will excite the Circulation, cause sudden Pains, and a high colour'd Urine; when Earth abounds the Juices will be too sluggish and gross, will excite Drowth, Leanness, Melancholy or Sadness, and Immobility; and when Oil is redundant the Person will be fat and unactive, and the Juices will be viscid, cold, and impervious. But to account justly for these Variations of Habit, the State of the Solids must be consider'd as well as of the Fluids; *per* §. 890.

§. 229. Finally, it is also evident from Experience, that the Blood's circulatory *Motion* only¹, causes and preserves its uniform Mixture, *Fluidity*², Heat, and Redness; since these Effects are either absent, or more or less

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present.

present, as that Motion is either destroy'd, augmented, or decreased.

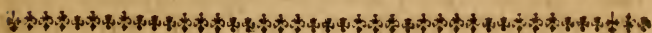
¹ The Blood when at rest or out of the Vessels, separates naturally into three different Parts, a vapour, a serous, and a crassamentum; but these constituent Parts do not depart from each other while it circulates with Motion enough in the Vessels. The same extravasated Blood also putrifies with a Heat of 90 gr. in the Space of three Days time, so as to exhale a most intolerable or offensive Stench; but by the Continuance of this circulatory Motion it will continue sound in the same Degree of Heat as long as the Animal is alive and well. Therefore the sound and healthy State of the Blood does not depend primarily on its constituent Principles but on this circulatory Motion.

² After the Blood has been extravasated a few Hours, its uniform Redness is for the most part changed into a yellow Liquor we call Serum, which being decanted from the Crassamentum, more Serum again flows from it, till at length the whole Mass is converted into that Liquor, leaving only a small Quantity of a grumous Substance behind: In the same manner will the firm Texture of the Blood dissolve and become serous in a less degree by a too slow Motion in the Body; so that by too much Rest or Inactivity, we shall either look pale, yellow, or green, from the Condition of our Blood and its Juices, as may be frequently observed in Women and Children. Upon this Account too Mr. Boyle and Dr. Bobnius never presumed to determine the Proportion betwixt the Serum and Crassamentum, because they observed more of either at one time than at another. The Redness and Compactness of the Blood therefore increases as its Motion, by whose Intensity its Surface will be
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sometimes spread with a whitish and tough Skin, like that of Trotters or Neats-feet, as may be frequently observed in the Blood of pleuretic Patients; and in Proportion as the Blood acquires more of this Thickness, so its Heat gradually increases, as we are taught by *Farenheit's* Thermometer.

§. 230. Having thus survey'd the Origin and Nature of the Blood and Chyle, it will be our next Business to examine what Alterations they undergo, as they are propell'd by the Force of the Heart and Arteries into the small capillary Vessels, spent in the Glands, Muscles, Emunctories, and Viscera: But of all these the Encephalon or Brain and its Appendages, deserves the first Consideration, as well because it receives the Blood from the Heart before any of the rest, as from its more immediate Concern in the Support of Life.



The Course and Action of the Arteries distributed to the Cerebrum and Cerebellum.

§. 231. **B**UT before we examine the Brain itself, we must first consider the Origin and Course of its *carotid* Arteries. Observe therefore that the *Aorta* having ascended a little above its Origin from the left Ventricle of the Heart, passes out of the Pericardium,

cardium, and is soon after bent in Form of an *Arch* ² or Curvature, from the right Side of which spring the *subclavian* ³ and right Carotid, which are conjoined in one for a little way, as if the latter arose from the former; but the left Carotid arises single from the Arch itself, from whence the two Carotids proceed in a very even or direct Course to the Cranium, in passing to which they are *defended* ⁴ by the *Aspera Arteria* and their deep Situation, without undergoing any Pressure or Incurvations, and hardly ever affording any *Branches* ⁵ by the way: Having almost reached the Cranium, they each of them send off an *external* ⁶ Carotid, and then entring thro' a bony *Channel* ⁷ in which they are secured, they are inflected therein forwards, put off their fourth or muscular Tunic (§. 132.) and give Branches to the Dura Mater; within the Cranium they are each again *defended* ⁸ by the Sides of the Sella Turcica, and a Process of the Dura Mater, and then expanding themselves on the Surface of the Pia Mater and Nerves, they divide into anterior, posterior, and lateral Branches, which are by means of the Pia Mater inserted into the Brain itself.

• Their Name is generally supposed to be derived from *Kαρες*, *Somnus*; because *Galen* deduces that Denomination of them from the Experiment of *Erasistratus*, viz. that upon making a Ligature on them the Animal falls into a Carus or Drowsiness.

² In Brutes who have long and pendulous Necks the Aorta divides into an ascending and descending Trunk; and Anatomists having taken their Figures of the Aorta either from them or from one another, has occasioned the Error of an ascending Trunk to be exhibited in most of their Books and Figures; none of them having given us a true Idea of the human Aorta except *Eustachius, Casserius, Lower,* and *Ruyfch.*

³ The right subclavian Artery is both nearer the Heart and of a larger Diameter than the left, whence it is that most People use their right Hand more than the left, as being from hence naturally stronger; but if the subclavian Arteries are both of equal Diameters, then the Person will be *ambidexter*; or if the left Subclavian be larger than the right, which seldom happens, then the left Hand will be more active and strong than the right.

⁴ The Windpipe projects out so far as to hinder any Compressure from reaching the carotid Arteries; whence it is that the Blood has a free Course to the Brain, by the Carotids, in those who are hanged and strangled with a Cord: But the jugular Veins lying but just under the Skin are so strictly compressed by the Ligature that no Blood can return by them, while the very little compressed Carotid and uncompressed vertebral Arteries (§. 232.) continue to urge the Blood on to the Brain, as in an Apoplexy.

⁵ You will not perhaps meet with any other Artery in the whole human Body that runs to such a Length as the Carotids without sending off any Branches.

⁶ The Blood is not absolutely of the same Nature in the external as in the internal carotid Artery, but undergoes a Kind of Separation or Preparation

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(per §. 224.) according to the Disposition of each Artery in order to Secretion.

7 To the Sides of which they grow, and are very firmly attached, so that they cannot be ever too much or too little distended in this Part, because the long Canal always keeps them in the same Diameter. In consumptive People, the whole Mass of Blood is frequently almost consumed to a few Ounces, but the internal Carotids are nevertheless equally full, from their Diameter being sustained by these bony Channels; whence the Senses and Intellects of such pthysical Patients are generally found and entire, even to the End of their Lives, notwithstanding the vast Decay in all the other Parts and their Functions.

8 The Dura Mater is firmly extended over the carotid Artery, as the Membrane is expanded over the Tympanum, that the Weight of the superincumbent Brain might not compress the same upon jumping, dancing, or any sudden Shock.

§. 232. But the vertebral Arteries arising from the upper Part of the Subclavians, ascend and soon enter the lateral Foramina of the seven Vertebrae of the Neck in which they are received, *defended*¹, continued directly forwards and secured with a vaginal Membrane or Integument, giving *Branches*² as they go, and when they emerge out of the Foramina of the Vertebrae, they are immediately after *incurvated*³ and inflected under and behind the upper Processes of the Atlas or *first*⁴ Vertebra, and becoming there somewhat enlarged, they then enter through the great Foramen of the Occiput, where depositing
their

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their thick muscular Coat, they afterwards unite and become much more capacious than before, and after communicating with the Carotids, they are then surprisngly ramified or *divided* ^s into Branches.

¹ Nature has been much more sollicitous to defend and secure the vertebral than the carotid Arteries from any Violence or Compressure; because the first convey Blood to the Cerebellum, upon whose uninterrupted Action Life, or the Motion of the Heart, immediately depends: But the carotid Arteries being spent on the Cerebrum, a Pressure in them is not so imminently fatal, producing only a Carus, Lethargy, &c. according to the Degree of Obstruction.

² In every Space betwixt each of the Vertebrae they send out an arterial Circle or Branch, into which the less moveable Particles of the Blood have a greater Tendence, *per* §. 224.

³ By these Incurvations the same Effect is obtained as if the Neck was made longer; *i. e.* the Interval and Resistance betwixt the Heart and Brain is thus increased.

⁴ In the first Vertebra or Atlas there is a Notch, through which passes the vertebral Artery, on each Side; but sometimes this Notch is formed into a compleat Ring or Foramen, as you may observe in the Skeleton of our *Leyden* Theatre, prepared by the famous *Vander Weil*; in which there is a compleat Canal in each Side the Atlas for the vertebral Arteries to pass through before they enter the great Foramen of the Occiput.

⁵ They particularly send off Branches call'd the Spinal Arteries, which descend on the fore and back Part of the Spinal Medulla, even down to

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Os Coccygis : So that after the Blood has ascended by the vertebral Arteries to the Occiput, it again descends in a retrogradé Course down the spinal Arteries twice as far as it ascended by the vertebral.

§. 233. We have therefore four Arteries (§. 231, 232.) ascending from opposite Sides, and mutually opening into each other in the Cranium, so as to form a sort of arterial *Circle*¹, from whence Branches are immediately detached, which meeting together and inosculating in the same manner, form lesser arterial Circles of the like *Kind*², in which Course they are again subdivided upon the whole Superficies of the Pia Mater, till they at last *disappear*³ or escape the Eye, insomuch that the whole Membrane or Pia Mater seems to be made up chiefly by such a Contexture of Arteries.

¹ By the arterial Circle, which is formed by the Union of the single or common Trunk of the vertebral Arteries with the two Carotids, the Encephalon is entirely preserved from dangerous Obstructions : For as no less than four Arteries conjoin to form that Circle, the Passage through three of them may be entirely obstructed, and yet the Brain and Cerebellum will be all over supply'd with Blood by the fourth ; nor do we know of the like advantageous Mechanism in any other Part of the Body.

² From the first or preceding arterial Circle arise perpendicular Arteries on all Sides, which inosculating with each other's lateral Branches, form
lesser

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lesser arterial Circles, from whence again spring other lesser perpendicular Arteriolæ, which again form still smaller Circles and lateral Branches as before, even to the smallest which escape the Sight.

³ We before observed, that the Arteries of the Brain deposit their thick muscular Coat before they enter the Cranium (§. 231.); and when arrived within the Cranium they again deposit the outermost of their remaining Coats which forms the Tunica Arachnoides, under which, the smaller Arteries, now consisting of but one thin Coat, are dispersed into an infinite Number of small Circles and Plexus's, which form that membranous Network of Vessels we call the Pia Mater, from which the very smallest of the Arteriolæ are detached into the cortical Substance of the Brain itself. *Vid.* §. 236.

§. 234. All the Blood therefore which is sent from the Heart to the Brain, is, by this mechanical Disposition of the Arteries, convey'd first to its thin Membrane the Pia Mater, from whence it passes into the Substance both of the Cerebrum and Cerebellum: For what other Blood is sent into the Cranium belongs only to the *Dura Mater* ¹ of the Cerebrum and Cerebellum, and is brought thither chiefly by two Arteries which spring from the external Carotids, and enter each through a distinct Hole of the Skull, distributing themselves laterally; to these add the Branches which come from the internal Carotids, thro' their Canalis Osseus, and spread themselves on the anterior Part of the *Dura Mater*; with those

those from the external Vertebrales, entring through the bony Duct of the Jugulars, and expanding themselves on the back Part of the Dura Mater; all which have been demonstrated by the accurate Repletion of these Vessels with ceraceous Injection by *Raw*², who was well versed in that Artifice. On the Account of these Arteries, the Dura Mater is furnish'd with strong Fibres next the Brain, to break off and sustain the Impulse of the Blood in its Arteries, and prevent any Injury from arising thence to so tender and important a Viscus. Lastly, the whole internal Surface of this robust Integument is lubricated, and prevented from adhering to the Pia Mater by a kind of serous or lymphatic Dew, which exhales not only in this but in all the other Interstices of the Body.

¹ There are two Sorts of Arteries within the Cranium; some which have a strong Pulsation like the other Arteries of the Body, and others, which, having deposited their muscular Coat, in a manner cease to be Arteries, and form a sort of intermediate Vessels betwixt an Artery and a Vein, having very little Motion, and uniting with each other into Plexus's like the Veins: But then these two Kinds of Arteries remain very distinct from each other, and have no Communication but in the Heart; for the beating Arteries are distributed to the Dura Mater only, while the soft venal Arteries are spent upon the cortical Substance of the Cerebrum or Cerebellum.

² The Arteries of the Dura Mater are chiefly the three before-mentioned, one from the external Carotid,

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Carotid, which comes to the Dura Mater through the sixth Hole of the Cranium; a second from the internal Carotid, as it comes through its Canalis Offeus, and a third from the vertebral Arteries, without the Skull: All which Arteries have no Communication either with the cortical Part of the Brain or Cerebellum. But the indefatigable *Vieussens* has affirmed, that the Blood passes from the Arteries of the Dura Mater into the longitudinal Sinus; which he says is a Piece of Conduct in Nature to render the venal Blood of the Sinus more fluid and less apt to coagulate: And adds, that he injected Ink and coloured Spirit of Wine by the carotid Arteries, in the Presence of several Physicians incredulous of his Opinion, which Liquors passed into the Sinus's. To be satisfied in this respect I desired my Friend *Ruyfch* to repeat the Experiment; in consequence of which he injected the carotid Arteries so exquisitely as to force his Wax through the small Arteries into their corresponding Veins, which open into the Sinus, into which the Injection had been strained through the small Anastomoses, so as to have none of its Pigment or Colour when it arrived in the Sinus's. This was therefore the way through which the Liquors injected by *Vieussens* had passed, *i. e.* thro' the Anastomoses of the Veins, and not immediately from the Arteries into the Sinus's. And in the Injection made by *Ruyfch* there were found continuous Cylinders of the Wax in the Anastomoses of the Arteries and Veins of the Dura Mater. *Raw* made the like Experiment at my Request, but could find no immediate Opening of the Arteries into any of the Sinus's.

§. 235. From this Course of the Vessels (§. 231 to 234. and the Nature of the Blood,

§. 224.

§. 224. whose Parts strictly observe that Rule of Motion) we may plainly perceive that the Blood arrives both in opposite Courses to the Brain, and in a more homogeneous and refined State than to other Parts; because as it approaches the Basis of the Cranium, it is there freed from the viscid Matter of the Saliva and *mucous Juices*¹; and the Blood of the vertebral Arteries will be more pure or less viscid by detaching the like Particles into its *lateral Arteries*², while its more gross and ponderous Parts will be also repell'd by the *Inflexions*³ in both the Carotids and Vertebrales; and again the Blood will be freed from its less moveable Parts in the *Caverns*⁴ formed by the Dura Mater at the Sides of the Sella Turcica, and the remaining grosser Parts will be sent to the Infundibulum and *Integuments*⁵ of the ten Pair of Nerves: From all which it follows. (1.) that the Blood arriving by the Vessels (§. 223.) in *opposite Directions*⁶, will impinge on that already in those Vessels, and retaining its original Nature, or having acquired one more refined, its Impetus will be so far *abated*⁷ as to hinder its compressing the soft and pulpy Substance of the Encephalon; (2.) will follow an intimate Commixture of all Blood brought hither, so as to become uniformly alike in every Part of it; (3.) an Attenuation, Levigation, and Attrition of its Parts, an Increase of their Fluidity, a Prevention of their concreting, and an Aptitude or Disposition of them for the subsequent Secretion; (4.) a less
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*Dilatation*⁸ or Pulse of the Arteries here, and a less Re-action of them on the Blood than in other Parts of the Body; and lastly, (5.) a Compensation for the Inactivity or Unaptitude of these large and small Vessels to transmit their Contents, by their inosculating so abundantly with each other, as gives the Blood a free *Course*⁹ from any one Vessel to the rest in all manner of Directions.

¹ For since the external carotid Artery arises or goes off laterally from the common Trunk, it will be most disposed to receive those Parts of the Blood which are least apt to retain their rectilineal Motion; and such are the Particles secreted by the four larger salival Glands, with the Mucus separated in the Membrana Schneideriana.

² Many Branches of the vertebral Arteries are reflected back or downward, and others go off at right Angles, both which will receive the less moveable Parts of the Blood, and separate from thence that fat Mucus which invests the spinal Medulla; therefore the more light, moveable, and spherical Particles of the Blood in the vertebral Trunks will go forwards or upwards to the Brain, while the more viscid and sluggish Parts recede from it into the lateral and retrograde Branches. I do not intend you should understand that all the smallest Particles of every kind in the Blood are thus convey'd to the Brain; but the smallest Parts which are dense and similar to each other, the smallest of the red Globules, the smallest of the serous ones, &c. *Vid.* §. 220 and 224.

³ The carotid Arteries are inflected as they pass through the Canal in each Os Petrosum, and the Vertebrales are inflected at their Ingress into the

O

Cranium;

Cranium ; both whose Inflections diminish the Impetus of the Blood brought to the Encephalon, and prevent it from rushing too impetuously upon the soft cortical Substance ; at the same time also, these Inflections augment the Length of the Canals, and increase their Distance from the Heart, so as to diminish the Impulse of the last.

4 When the Blood of the carotid Arteries has passed into the Cranium, it again meets with another Inflection or Remora in these Caverns, where it also enters a Set of small Arteries expanded and interwove like a fine Net, whence it has been denominated Rete mirabile, being by much the most conspicuous in Brutes ; into which Plexus are detached the more sluggish Parts of the Blood, whose Impetus or Velocity is here abated.

5 The vaginal Integument of the Nerves, coming from the Pia Mater, receives Branches of the carotid and vertebral Arteries, which appear very red and conspicuous by Injection.

6 There are many Advantages attending this mutual Intercourse of the Blood in opposite Directions ; for it will by this means obtain an intimate Mixture and Attrition of Parts (*per* §. 220. N^o 3, 4.) by which they will be attenuated and rendered more fluid, so as to prevent any Grumes or Concretions, to which the Blood would be otherwise very liable in its Passage through so very small Vessels unagitated by any Muscles, and even without the Action of a muscular Coat, observed in all the other Arteries. Another Advantage is the Diversion of the Blood's Impulse and Velocity from injuring the tender Substance of the Brain ; to abate which nothing can be more effectual than the many Inflections, lateral Ramifications, mutual and infinite Inosculations of small Vessels exerting little or no Re-action ; by which means the Blood will lose
much

much of its Force against the Sides of the Vessels, and against the other Blood which meets it in opposite Courses. *Vid.* §. 215. N^o 2.

⁷ That the tender cortical Vessels might not be broke or over-strained beyond their Tone or Elasticity by too great an Impulse of the Blood ; for the entire Serenity or right Composure of the Mind depends altogether on the Arteries of the Brain resisting the Impulse of the Blood to a proper Degree ; below which, a less Resistance confounds the Mind and disorders its Faculties. *Peyerus* having ty'd one of the jugular Veins in a Dog, he soon after became stupid, and made many odd sporting Gestures, till at last he fell into a dead Sleep, from a too great Distention of the Blood-vessels in the Brain ; from which Cause alone, in various Degrees, may be produced all the several Disorders of the Brain. And a too great Plenitude of the Vessels in the Brain, from a Stoppage of any Evacuation, will have the same Effects. Those who either die phrenitic or strangled have the Blood-vessels of the Pia Mater so turgid and full that they are ready to burst. To prevent such a Redundance and too great Impulse of the Blood on the Brain, Nature has used many Precautions ; the Inflection of the Trunks, the Division of them into lateral Branches, and the Subdivision of their smaller Branches within the Cranium into several Series, which inosculate together, and expand themselves circularly about the Brain before they enter its cortical Substance. Headachs which very easily supervene a little increase of Exercise or muscular Motion demonstrate that these Vessels are in danger of a Rupture.

⁸ I was formerly seduced, by the specious Arguments of *Baglivi* and *Pacchioni*, to think that these Arteries had a Pulsation like the rest in the Body ;

but I know, by Experiment, that the Arteries of the Brain have not a Systole and Diastole like others, nor are they fill'd alternately, but continue equally and moderately distended; for so soon as they begin to beat or vibrate, the Senses are constantly disordered. I took off the Top of the Cranium in a living Dog, and could then see the Arteries of the Dura Mater vibrating so strongly as might well impress their Figure on the solid Plates of the Skull; for such was their Motion, that they agitated both the Dura Mater and its Sinus's, as if they had a Pulsation in themselves: But upon removing the Dura Mater, the Brain appeared quiet with distended Arteries, but without any Pulsation; at which several learned Spectators of *Baglivi's* Opinion were highly surpris'd, since they expected to see the whole Brain jump up at every Systole of the Heart.

9 From hence it is that Wax being injected by one Artery of the Brain, it runs into all the rest. From this Principle too, no one Part of the Brain will be more pressed than another; for if the Blood ascends more forcibly by the carotid than by the vertebral Artery, it will not press stronger on any Part of the Brain than the vertebral, by means of their Communication with each other, whence every Part of the Brain will be equally supplied with Blood, and one Part will receive as much Spirits as another. From hence too it is that a Man may live notwithstanding, his carotid Arteries are obstructed or become ossified, so as to be unable to propell the Blood; for then the vertebral Arteries will convey more Blood than before, and propell it both into the Carotids and into the whole Surface of the Brain: Whence also, when one Part of the Cortex is destroy'd, suppurated, or loaded with a Fungus, none of the Functions

are

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are thence injured, because the remaining Vessels of the next adjacent Stratum of the Cortex supply the Defect; for the Cortex of the Brain is composed of an infinite Number of Lamellæ or Strata of small arterial Vessels, the largest of which lie outermost, and under them smaller, till you come to the last Stratum of the smallest of these Vessels, under perhaps a thousand of the larger, from which last Stratum arises the Medulla of the Brain. So that if you remove all the outermost Strata from a Part of the Cortex, and leave only that which is next the Medulla, the adjacent Strata will then supply this last by their infinite Anastomoses continuing all the way from one Stratum to another beneath the first, so that the Secretion will be nowhere lost, but the whole Origin of the Nerves will be supplied with their Juices.

§. 236. Now these Arteries of the Brain being thus interwove, and secured in Order (§. 233.) in the Pia Mater, as in a Stratum or Basis which is incredibly thin, and like a *Spider's Web* ¹, do, from every Point of the said Membrane, detach small arterial Branches almost in a perpendicular Course, which winding and inosculating with each other like the first, form, as it were, a Membrane, by whose Insinuation the external Substance of the Brain and Cerebellum is divided into winding *Furrows* and *Ridges* ², so deep as to reach almost down to the *Medulla* ³; only the Sulci or Furrows in the Cerebellum are not near so deep as those in the Brain. But these Ridges, convoluted in the Form of Intestines, are again resolvable into lesser ones,

like the former, being all of them framed by the Insinuation of the Pia Mater, and appear to contain red or sanguiferous Vessels only ⁴ in their exterior Surface, which Vessels they convey to the Surface of their subjacent or included Substance. But then this included *Substance* ⁵ of the Ridges, which makes up the greatest Part of them, never receives any sanguiferous Artery or Vein, nor could it ever be injected or tinged of a red Colour; and as for that Part of this Substance which remains after macerating Portions of the Cerebrum and Cerebellum in Water, having first filled their Vessels with ceraceous Injection, and freed them by Abrasion or shaking from the said Substance, it appears like a Congeries of minute Vascules in Form of Down or fine Wool, which are so soft, juicy, and tender, as to break with the least Force imaginable, and dissolve into a purulent or *pulpy* ⁶ Juice, barely by suspending them in simple Water.

¹ Whence the external Lamen of this Pia Mater, formed by the Deposition of the more dense Membranes of Tunics of its small Vessels, is usually denominated Arachnoides Tunica, which is said to be destitute of Vessels; at least it has none that we can discover either by the Eye or Injections. But I am certain there is no other Membrane under the Arachnoides besides the small Vessels themselves, which are interwove into a very thin Covering investing the cortical Substance, being almost as fine and much weaker than the Web of
some

some Spiders. In a Word, the Pia Mater is the first Stratum of Arteries belonging to the Cortex of the Brain; and the Cortex itself is an infinite Number of pellucid, arterial Strata from the Pia Mater, containing one within the other.

² These Gyri or Convolution in the Brain have several Uses or Advantages; as (1.) to increase the Surface of the cortical Substance, and consequently its Secretion; (2) to bring the Cortex into Contact on all Sides with the medullary Fibrils or Tubuli, that its last Series of Vessels may discharge themselves with more Certainty into the said Tubuli or Fibrils of the Medulla.

³ The Ancients took the Pia Mater not for a Part of the Brain, but only for its interior Capsule, and the Dura Mater for its exterior Capsule, *Ruyfch* has demonstrated to us, that the Pia Mater is inserted on all Sides of the Brain down to the Bottom of its Sulci, from whence it rises up again to cover the next Ridge: And in this manner it descends from the Top of one Hemisphere of the Brain, and, after reaching the Corpus Callosum, it returns up to the Top of the other Hemisphere.

⁴ This is sufficiently proved in the Brain of such as have been hanged, in which the Blood being impelled into the Arteries of the Pia Mater with the whole Force of the Heart, and being obstructed in its Return by the Veins, renders the Blood-vessels as full and turgid as if they had been injected: But even in such we never observe any red Blood in the cortical Substance of the Brain, but its Progress is confined within the Vessels of the Pia Mater.

⁵ The celebrated *Ruyfch* having moderately fill'd the Arteries of the Brain with ceraceous Injection, by the Carotids, he then opened the Dura Mater,

and took out the injected Brain, whose cortical Surface appeared red only in some Parts, not all over. He took a Part of this Cortex with its injected Artery and macerated them in warm Water till a Putrifaction began to appear, and then gently and frequently shook the Mass in the Water to separate the Tunica Arachnoidea; which Operation he repeated till the Water became foul with the infinite Number of small white Flocculi washed off from the cortical Substance; but when the Water appeared no longer foul, retaining its original Clearness, he then removed the unravell'd Cortex, and suspended it in Alcohol Vini, in which it appeared like a little red Fleece of fine Down or Wool, being only a Bunch of the small arterial Vessels fill'd with the Injection. Thus all the small Vascules which were not entred by the Injection were dissolved and lost in the Water, and those only remained sound and entire which the Injection sustained and preserved from Corruption; so that all the venal and smallest arterial Fabric of the Cortex was thus destroy'd: But as many of the small Arteries thus preserved and injected are found to be fifty and a hundred times smaller than a Hair of one's Head, how vastly smaller must those be which were dissolved and washed away, as being impervious to the Injection. Nor does this Artifice demonstrate to us the true Nature and Mechanism of the Cortex, since the greatest Number of the Vessels are thus destroy'd, and the Remainder dislocated or unravell'd. It is observable that *Ruyfch* only used the Heads of immature Fœtus's, or of new-born Infants for these Preparations.

⁶ Being assisted by the Experiments of *Ruyfch* and *Lewenboec*, I can now boldly assert, that the Blood does not circulate through the internal Substance of the Cortex of the Brain, notwithstanding there

there are so many sanguiferous Arteries and Veins spread on its Superficies ; for the red Parts of the Blood only circulate in the Vessels of the Pia Mater, the internal Part of the Cortex next the Brain being quite pellucid. This is true, notwithstanding there are some sanguiferous Vessels observable in the medullary Part of the Brain, which perforate the Cortex and Medulla perpendicularly from the Pia Mater, without spreading into Branches, and seem designed to communicate Warmth to this Part. I desired *Lewenboec* to examine the cortical Part of the Brain with his Microscope ; but his Answer was, that he could see nothing but pellucid Globules. And *Ruysch*, by his forementioned Preparation, has demonstrated that the cortical Substance is a Congeries of small pellucid Vascules like fine Wool, continued from the interior Blood-vessels of the Pia Mater. It follows then that the Cortex is composed of Vascules continuous with those of the Pia Mater, which admit only pellucid Parts of the Blood, and disposed in Courses not yet known. We know that the small Vessels are distributed in a different Course in every particular Part of the Body ; and no doubt but they have a distinct and different Position in the cortical Substance of the Brain, tho' their Minuteness and Pellucidity conceal the same from our Eyes. But this we may reasonably conclude, that they retain the same Disposition in every Brain ; for if they varied in this respect the reasonable Faculties of Men would be different : And we see that so small a Change or Distortion of their Course, as is produced in Drunkenness, makes the same Man act and think very differently from what he would if he was sober. Lastly, those red or sanguiferous Vessels which some Authors ascribe to the cortical Substance of the Brain, are nothing more

more than Part of those belonging to the Pia Mater which were broke in the Separation.

§. 237. The external, *ash-coloured*¹, *soft*², and moister Substance is termed the cortical Part of the Brain and Cerebellum, which every way exactly invests the whole Origin of the other internal, more white, dry, and compact Substance call'd their medullary Part: Even this latter manifestly appears to arise every way from the *former*³, especially in the Appendices, Ventricles, Crura, and Medulla *oblongata*⁴; but on the Reverse, the internal Part of the *spinal*⁵ Medulla appears like the cortical of the Brain, like which it is also spread with Arteries, and is encompassed with a white medullary Substance.

¹ This Part indeed appears red in phrenitic Subjects, and after the Brain has been injected; but in a healthy State it never contains any of the red Globules, but appears pellucid and a little bluish like Glass, approaching nearer the Consistence of a Fluid than a Solid, so that it cannot be cut, even by a Razor, without sticking to its Sides: And if you ever observe any Blood or sanguiferous Vessels herein, they must have been tore from the Pia Mater; for the red Blood and its Vessels are always seated upon the Surface, and not within-side the cortical Substance of the Brain.

² So soft and tender as to dissolve in an aqueous Liquor, and in the open Air almost wholly evaporates in a few Days.

³ *Piccolbominus* first distinguished the cortical from the medullary Part of the Brain, and observed

served that the Medulla terminated in that Part of the former which was remotest from the Pia Mater, being proportionably thicker where the cortical Part is thicker, and thinnest where it is covered with the least Cortex; only in the Basis of the Brain there is more Medulla than Cortex, because the latter is here collected from the other Parts of the Cortex. The Medulla also appears to consist of Filaments or Ducts arising from all the Gyri or convex Ridges, from whence they converge towards a Center. But we do not observe any such Connexion betwixt the Cortex and Medulla in the Corpus Callosum, in the Corpora Striata, in the Thalami of the optic Nerves, nor in the Peduncles of the Brain and Cerebellum; for in those the Medulla is naked and covered only with the Pia Mater without any Cortex; but then the Pia Mater does not here give any Vessels to the Medulla, nor does it send down any Partitions as in the Cortex, but only serves as a Covering.

4 The whole Medulla of the Brain and Cerebellum is collected into four Trunks or Stalks, call'd Crura, excepting what goes to the olfactory Nerves, which do not arise, like the rest, from the Medulla oblongata, but from the anterior Lobes of the Brain itself, for which Reason they were rather termed Processes than Nerves by the Ancients.

5 For so is call'd the Medulla oblongata, after it has sent out the ten Pair of Nerves. Nature seems to have chose this Inversion of the cortical Substance here, for the more commodious Distribution of the Nerves from the medullary Part; for if the Medullary had been included in the cortical Substance of this Part, the Nerves must have perforated the latter as they pass out from the former. Another Reason was to prevent the Medulla Spinalis from being compressed, to the Hazard
of

of Life by a Surcharge of its cortical Substance with Blood in violent Exercises and Commotions, to which it would have been liable if disposed like the Brain; but under the present Circumstances there is a free intermediate Space left betwixt the Medulla Spinalis and its Theca or Case of Vertebræ, sufficient to preserve it from any Pressure, which would be follow'd with fatal Consequences.

§. 238. But in the *Cerebellum* ¹, those two Substances (§. 237.) are so apparent or conspicuous, that you may there plainly perceive the manner in which the Medulla arises from the Cortex, with its Proportion, Fabric and Divisions: You will also constantly observe the cortical Part of the *Cerebellum* to be firmer than that of the Brain, and more inclined to a yellow Colour.

¹ In this Part the Medulla appears beautifully divided into many small Branches, like a Tree, among the cortical Substance, into which it appears plainly to be continued.

§. 239. Since therefore a very large Portion of the *Blood* ¹, computed by *Malpighi* at one Third of the Whole, is impell'd in a direct and swift Course to the cortical Part of the Brain at each Systole of the Heart, it will thence receive a Motion of Dilatation and Constriction, though but *small* ², so long as its arterial Vessels are thus fill'd with Blood: But as we are assured there are Arteries here, we know too that there must be small *Veins*:
every

every where at the Termination of those Arteries, though they are not visible, through their Smallness and the Thinness of the Membranes; there must be also some secretory Canals, arising every where from the smallest or last Series of Arteries in this Gland, in which there must be also corresponding Emissaries or excretory Ducts, though neither can be distinctly seen.

¹ That we may the better credit the Computation of this great Man, we ought first to examine the Diameter of the carotid and vertebral Arteries, and then compare the same with the Diameter of the Subclavians and descending Aorta; and if we find they are not quite so large as to receive one third Part of the Blood, we must make some Allowance for their Vicinity to the Heart, and the Straitness of their Course to the Brain (§. 231 and *seq.*). And they cannot receive much less Blood than what is computed by *Malpighi*, if we consider the vast Bulk or Quantity of the human Brain, weighing four or five Pounds, or thrice as much as that of an Ox; and considering too that it is composed of mere Vessels without any Fat or thick cellular Membrane, with which most of the other Viscera are loaded; from whence it is that the Brain never shrinks or wastes like the other Parts of the Body in Consumptions. Add to this, that the vascular Compages of the Brain is not subject to the Pressure of any Muscles, like the other Viscera; nor are its Trunks of its Vessels liable to be compressed by the Action of any Muscles.

² Dr. *Ridley* (Phil. Transf. N^o 287.) having removed the Top of the Cranium in a living Dog,
and

and cut open the Dura Mater, perceived that the Brain itself had an alternate Subfultus or vibratory Motion corresponding to that of the Heart ; but it must be observed, that this Subfultus is occasioned only when the resisting Bones of the Cranium are removed : For while the Cranium is entire, as it closely invests the Encephalon, and is quite fill'd therewith, this latter can have no Diaſtole or vibratory Motion without removing the Sides of the Cranium, which cannot be dilated by the Force of the Heart and Arteries. Nor will the Brain and Cerebellum have any Syſtole or Contraction, ſince their Arteries have no ſtrong muscular Coat to contract them ; whence it follows, that the Veſſels of the Encephalon will remain nearly equably and continually diſtended. We may however conclude the Brain has ſometimes ſuch a Motion in a ſmall Degree, from the Obſervation of *Malpighi*, who, upon awaking out of his Sleep, had a Senſe of Light ſaſhing in his Eyes when the Pulse dilated, and an Eclipse or Darkneſs when the Arteries contracted, which was alſo attended with a Senſation like a tremulous Motion in the Brain. But ſuch a Senſe of a vibratory Motion in the Brain can be only perceived in a Morning, when the Senſes are the quickeſt, and the Sensorium the ſtrongeſt ; agreeable to which *Mr. Boyle* obſerves, that a blind Muſician had ſuch an exquisite Feeling in the Papillæ of his Fingers Ends that he could diſtinguiſh the Colour of Objects merely by that Senſe, which he enjoyed in the greateſt Perfection betimes in a Morning ; from whence it diminifhed, till by Noon he could feel no better than other Men ; concerning the Truth of which *Mr. Boyle* was ſatisfied with his own Eyes at the Expence of a long Journey. Therefore the Arteries of the Pia Mater ſeem to propel their Blood forwards in a quiet and even Stream,

Stream, which though not equally swift, is yet so smooth and equable in a healthy State, as not to agitate the Sensorium nor disturb the Faculties.

³ *Drelincourt* affirms, that the Pia Mater only is furnished with sanguiferous Veins, and that the Cortex of the Brain has none; which Notion I take to be just, being persuaded that the Arteries of the Pia Mater, under the Tunica Arachnoides, are divided into exceeding small Branches, which being reflected back in an opposite Course, enlarge and form the sanguiferous Veins of the Pia Mater; being those Veins through which the Injections transfused into the Sinus's of the Dura Mater at §. 234. N^o 2. But the Reason why the ceraceous Injection in that Experiment passes into the Sinus's without its Colour or Pigment, and in little broken Threads distinct from each other, may be understood from the Smallness of the Anastomoses betwixt the Arteries and Veins, which kept back the gross and ponderous Parts of the Pigment or Cinabar, and the finer Part of the Injection passing on into the diverging Veins with a diminished Velocity, must retain the Shape or Form of the small cylindrical Anastomoses, or appear like broken Threads.



*Of the different Structure of the
Glands.*

§. 240. **T**HE exceeding Minuteness of these Vessels in the Brain and Cerebellum, concealing their Fabric from our In-

Inspection, has occasioned Reason, though unassisted with its proper Evidence, to attempt at supplying the Defect of Sense by Analogy; whence various Opinions, of which the most received was that of *Malpighi*, supposing the Fabric of this Viscus to be glandular, till the contrary was asserted by the celebrated *Ruysch*, who has excell'd all Anatomists in the Art of demonstrating and preserving the smallest arterial Vessels in the Body. Therefore, before we can judge of the Merits of either Opinion, we must first consider the Bodies we call Glands, according to the Discoveries made of them by *Sylvius*, *Steno*, *Wharton*, *de Graaf*, *Malpighi*, *Bellini*, *Borelli*, *Pyerus*, *Nuke*, and *Ruysch*, who have best treated on the Subject.

§. 241. Of these *Glands* ¹, some of them are *simple* ², and others compound, or an Assemblage of simple ones invested with one common Membrane or Integument. The simple Glands separate their Juice from the Arteries, and convey it by their lymphatic Ducts, either into the Chyle, or the venal Blood, or else exhale it on the Surface of the Skin externally, or of the *Membranes* ³ internally, throughout the whole Body: But the compound Glands discharge their Juice, separated in every simple one, by a small Duct continued from each, into one large Canal or common Emissary, which either opens into some ample Cavity, as of the Mouth and Intestines, or else discharge themselves out of the

the Body, for various Uses, and are, from their Appearance, often termed conglobate, and conglomerate.

¹ The outward Appearance of the several Glands is so very different, that it is next to an Impossibility to frame a Definition adequate to all the Variety of them : If we define them, with *Pyerus*, to be secretory Organs, from their Office, that indeed agrees with all of them ; but then are there not more secretory Organs than Glands, as the Lacteals, Vasa Exhalantia, &c. ?

² This Name is proper to a Kind of Cells (*Folliculi vel Cryptæ*) formed each of a single Membrane convoluted so as to include a hollow Space or Cavity, on the Convexity of which the small Arteries are disposed, and distil Part of their Contents by open Orifices into the said Cavity ; from whence the secreted Juice is discharged by a small Tube call'd its excretory Duct, after it has been secreted, retained, and altered in its Follicle or Crypta. Of this Kind are the simple, mucous, and sebaceous Glandulæ in various Parts of the alimentary Tube and in the Skin ; and sometimes several of these unite their excretory Ducts, as may be observed in some Parts of the Fauces, Intestines, Urethra, &c. These have been termed conglobate by *Malpighi*, though other Anatomists generally give that Name to the lenticular Glands in the Mesentery, Groins, Arm-pits, Face, and Neck, &c.

³ If a Portion of the Skin or Pericardium be compressed betwixt the Fingers, you will perceive Pores or Orifices from whence a soft or fluid Matter issues, more fluid from the latter than the former.

§. 242. The simple or smaller Glands (miliary, lenticular, multiform, &c.) are composed (1.) of a thin, uniform, external Membrane, and of another adhering closely to the former internally. The *first* ¹ of these, consisting of circular and elastic Fibres, every way invests, presses, contracts, and empties the Gland, which consists chiefly of a Contexture of small Vessels passing into and out of the said Membrane : But the latter Integument of the Gland, being *thicker* ² and more compact than the first, detaches its Fibres in all Directions among the small Vessels, rendering their Contexture very intricate, and has much the same Uses with the first. (2.) They receive *Arteries* ³ whose Branches are disposed and secured in a certain Order by the preceding Membranes, which so accurately retain and distribute the Arteriolæ to every minute Part of the Gland, that upon injecting them with Wax or Mercury, the small Arteries become thereby so much distended, and the other smaller Vessels so much compressed, as seemingly to prove the *false Notion* ⁴ of their whole Fabric being only arterious. (3.) They are also composed of *Veins* ⁵ disposed and secured like the Arteries. (4.) They receive a great many *Nerves* ⁶, more, in Proportion to their Bulk, than any other Part of the Body ; and which are distributed so minutely throughout the whole Body of the Gland that they seem to occupy every individual Point. Lastly,

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ly, (5.) they are also furnished with adductor and reductor *Lymphatics* ⁷.

¹ This Integument consists almost intirely of small Arteries and Veins, which in a healthy State are not visible, but appear large in Tumors and Cancers of the Glands, as if they were distended by Injection. 'Tis not easy to distinguish this Membrane from the next in sound Glands without boiling, which shrinks and elevates the first Integument, betwixt which and the next you will perceive the small Arteries and Veins distributed to the Body of the Gland, as they are generally distributed betwixt the Duplicatures of the Membranes in other Parts. The very accurate *Morgagni* has also observed, that the Fat or cellular Membrane is interposed betwixt these two Integuments of the Glands.

² This Tunic is found so robust and firm in the Glands of the Mesentery that the Knife can scarce enter it; and the Tunica Vaginalis of the Testicles *Malpighi* has sometimes found half as thick as ones Finger. This Integument confines the tubular Compages of the Gland, which breaks out and unravels when this resisting Membrane is in any Part destroyed: And when a Cancer has eroded the external Tunic of a Gland, a frightful Tumor always sprouts from the Ulcer, from the degenerating of this Part, as in Cancers of the Breasts.

³ These Arteries are so numerous in the small Glands of the Mesentery, that, after Infection, the whole Substance of the Gland seems to be composed of Arteries, which deposit their external Tunicks to each Gland before they enter its Substance, as manifestly appears in the smaller Glands of the Mesentery, and in the Kidneys,

* *Ruyfch* having perfectly injected the Arteries and Veins of some Glands, afterwards macerated them in Water, and by shaking, unravell'd or separated them into little Bunches, like Wool, every where fill'd, without perceiving any Follicles or Cells among them. But his ceraceous Injection was forced only into the sanguiferous Arteries and Veins, which are the largest in the Body, so that the smaller and thinner Vessels interposed betwixt them were thus compressed and obscured, and afterwards dissolved; for all Parts of the Body dissolve in Water, if they have no Support to hold them together internally; (upon which Principle the whole Mass of fleshy Parts dissolve in Water from the Bones, so as to leave what we call natural Skeletons, connected together by their Ligaments without the Assistance of Wires, of which sort we have one prepared and given to our anatomical Theatre of *Leyden*, by *Vander Wiel*) and therefore we may safely affirm, that by this Method of preparing the Glands, their minutest Vessels and thin membranous Folliculi or Cells were dissolved and washed away in the Water.

5 After *Ruyfch* had fill'd only the Veins of the mesenteric Glands as full as possible with his Injection, they appeared so numerous and distended, that the Glands, which before appeared wholly arterious, seemed now to be nothing but a Compages of small Veins; as they very well might, since the Veins are six times more capacious than the Arteries. But the red Blood, brought by the sanguiferous Arteries, is returned again by their Veins without entring into the innermost Recesses of the Gland, termed its Follicles or Cells.

6 'Tis remarkable that the conglobate Glands receive more small Nerves than any other Part of the Body of the same Bulk; and the Glands
of

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of the Breast being so very nervous, are of all Parts the most apt to turn cancerous, when they are any way ulcerated : But that Cancers arise from an Irritation and Destruction of these glandular Nerves, may appear from Experience, by which we observe how easily a Wart becomes cancerous by bad Treatment, being an exuberant Fungus of the nervous Papillæ ; and this seems to be the Reason why Ulcers are often so stubborn and incurable in glandular Parts. But as these Glands have neither any considerable Motion nor Sensation, their Nerves seem to be designed for some other Office in them, which is probably to mix and pour out some of their nervous Juice into the Liquor secreted in every Part of the Gland.

⁷ This has been demonstrated by *Nucke*, that in all Parts of the Body the conglobate Glands have Lymphatics which pass into and out of them : Even the Lacteals which are one Kind of Lymphatics, do not pass to the Receptacle of the Chyle or the thoracic Duct before they have passed thro' the Glands of the Mesentery, from whence they pass out and are distributed again. And as the sanguiferous Arteries convey their red Blood in corresponding sanguiferous Veins, so the pellucid Juices, which are thinner than Blood, pass out of their lymphatic Arteries into lymphatic Veins ; and we know that Water being injected by the spermatic Artery of the Testicle, will pass into and fill its Lymphatics, as it also will distend the Lymphatics upon being injected into the Arteries of other Parts.

§. 243. We must also observe, that these Arteries of the Glands are conical and elastic Canals, variously inflected, ramified, and

convoluted, till at their Extremities they become *cylindrical* ¹, and change into Veins without any farther Ramifications ; but then before the small Arteries are thus changed into Veins, they communicate with each other by an infinite Number of *Anastomoses* ², their lateral Branches are sent off in different Angles, and are very differently *disposed* ³ in different Glands.

¹ Every Artery gradually diminishes its Diameter as it sends out more lateral Branches, contracting itself towards an Apex like a Cone ; but when it has done ramifying, there is then no Necessity for it to converge, but it continues its Course cylindrically, as we see by the Microscope, in the Fins and Membranes of Fish and Frogs. Such a cylindric or evanescent Artery either continues in a reflected Course to become a Vein, or else discharges its contained Liquor by a patent Orifice externally on the Surface of the nearest Membrane ; and as the Arteries thus terminate cylindrically, so the Veins begin or rise in the same manner, and by uniting themselves gradually acquire a larger Diameter like a Crescent or inverted Cone.

² No Affection of the Arteries has been more accurately considered by *Bellini* than this of their inosculating with each other by Anastomoses ; from whence he demonstrates that the Particles of the Blood impinging against their Angles will be divided and broke, like as a Drop of Water falling from some Height on an Obstacle flies asunder into many smaller Drops. As a great many of these angular Divisions of an Artery may be retained in a very small Compass or Point, it follows that the Blood may be divided into above a thousand lesser

Par-

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Particles merely in one arterial Spot or Bunch thus formed, than it would by passing on in the same Vessel continued at length. Thus it is, that the Parts of the Blood are prepared for Secretion in the Glands, and divided to enter the secreting Orifices ; and from the frequent Incurfions, its Parts will also acquire a rotatory Motion, like the Blood in the vascular Plexus of the Lungs, §. 200. 'Tis also by these Anastomoses, that when Particles of the Blood cannot go on freely, because of some Obstacle or Obstruction, they return back in the same Artery to the first Inosculation, and go on laterally another way without any Impediment. This was first observed by *Lewenboec* in a Bat, and after him by others in Quadrupeds ; and I have myself observed the same in Men when they have turned pale with a sudden Fright.

3 The elegant Figures and Preparations of *Ruyfch* sufficiently demonstrate that there are not two Arteries distributed alike throughout the whole Body ; for some run parallel, others in Arches, some in Heaps or Convolutions, and others in Webs or Plexus'd ; some are disposed in Bunches like Pencil Brushes, &c.

§. 244. Therefore the arterial Blood being propell'd to the Glands suffers there a great Agitation, *Repulsion* ¹, Compression, its Parts are both pressed laterally and against the Sides of each other, their Contacts are continually changing, and they are forced every way, and presented to every individual Point of their containing *Vessels* ², whence a perpetual Rotation and *opposite* ³ Pressure of every Particle, by which they will recede laterally and run into the Branches, so as to be divided or attenuated,

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nuated, ground together, compacted, polished, mixed, *kept fluid* ⁴, and finally *secreted* ⁵.

¹ The Blood pressed into the Artery by the Force of the Heart will be repell'd and resisted by the preceding Blood, which must first be urged forward before the other can succeed ; the propell'd Blood will also be repressed or re-acted on by the Sides of the Artery it dilated ; whence every Particle of the Blood will be pressed in all Directions against those in contact, and will not have any single Point unresisted.

² The smaller the Vessels the more of the Particles of the Blood will be impell'd against their Sides. (§. 213, 215.)

³ There is a threefold Pressure upon every Particle ; (1.) from the Heart, which urges the Blood forwards ; (2.) the Re-action of the Globules of the preceding Blood pressing back upon that which follows ; (3.) the lateral Pressure from the Arteries acting perpendicular to their Axis, and opposite to the two former.

⁴ No Part of the Body is sooner or more easily obstructed than the conglobate Glands ; even among ten Persons who expire of chronical Diseases, one may safely venture to affirm that nine of them will be found to have an Obstruction in the lymphatic Glands, either of the Mesentery, Neck, Throat, or some other Parts of the Body.

⁵ Of these secreted Particles there are two Kinds ; some of which are of the smallest Size in the Blood, passing out of a larger into smaller Vessels ; and others which will be protruded by the Arteries into some common Cavity or Receptacle.

§. 245. Now every arterial Branch arising from a Trunk is found to be *smaller*¹ than its Trunk in the larger Arteries, and therefore we may conclude it is so with smaller; whence the smallest or ultimate Branches will be also less than their ultimate Trunks: Therefore the ultimate sanguiferous Arteries will transmit the thicker Parts of the Blood into the incipient sanguiferous Veins, while their smaller Branches receive the more thin, fluid, and pellucid Parts of the Blood, less than the Diameters of their Orifices, into which they will be pressed by a considerable opposite or oblique Force.

¹ Every Artery in the human Body is larger than any Branch that it emits, as we are assured by our Senses, so long as the Eye or Microscope can trace them; and it is doubtless the same in those exceeding small Arteries whose Minuteness and Pellucidity conceal them from the Eye, both naked or armed. But the Particles of the contained Fluid will be always in Proportion to the Diameter of their Canals; so that if a small Artery admitting only single red Globules is ramified, all its Branches will be less than those Globules, which they therefore will not receive; but they will admit those Parts of the Blood which are less than the red Globules, or which are proportionable to their Diameters, while the larger red Particles will pass on into the red or sanguiferous Vein. But the next lesser Parts of the Blood to the red Globules are the yellow ferous ones (*per* §. 226.) and therefore the lateral Branches of the smallest sanguiferous Arteries

teries will be fill'd with ferous Globules, and constitute a second Order of Vessels, *viz*, ferous ones. That there are such ferous Vessels is proved by the Microscope, Injections, and to the naked Eye in an Ophthalmia, where the Cruor is forced into the ferous Vessels of the Sclerotica. But these ferous Arteries again dividing into smaller Branches like the sanguiferous, will at last send out Branches of less Diameters than their yellow ferous Globules, and these Branches will therefore be fill'd with the lymphatic Globules, which are the next less in Size to the yellow ferous ones, and constitute a Set of Arteries of the third Order, termed lymphatic Arteries, such as furnish the aqueous Humours of the Eyes, which Humours are absorbed or returned again to the Blood by ferous or lymphatic Veins. Hence then, the sanguiferous Arteries will carry all the Parts of the Blood, the ferous Arteries will convey all but the red Globules, and the Lymphatics all but the red and yellow Globules, &c. and thus probably is the Succession of Vessels and Humours continued, till the ultimate or last Series of the smallest Vessels convey only the most subtile Juices in the Body. We are sufficiently convinced that there are Humours much more subtile than the Lymph, such as the exhaling Vapours which do not become visible unless condensed by the Cold upon a Glass, &c. to which we may add the natural Sweat or perspirable Matter which constantly exhales from the Body, and will obscure a Looking-Glass held at some Distance, but quickly evaporates again from the Glass without leaving any Spot or Residuum; whereas the Sweat that is forced or arises by Exercise, &c. is so viscid that it can scarcely be wiped off from the Glass, and leaves permanent yellow Spots behind it. Since therefore we are thus convinced that there

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are Liquors in the Body more subtile than the Lymph, we may rest equally satisfied that there are also smaller Arteries which convey them, and which arise from the lymphatic Arteries in the same manner as they arise from the serous, and the serous from the sanguiferous.

§. 246. But the more subtile Juice which thus passes from the sanguiferous into the smaller Vessels is no longer Blood but a *different* ¹ Humour, turning either to *Sweat* ², the Matter of the *Pores* ³, *Perspiration* ⁴, *Tears* ⁵, *Ear-wax* ⁶, a *sebaceous Matter* ⁷ betwixt Fat and Wax, *Mucus* ⁸, *Saliva*, *Sputum* ⁹, *Lini-ment* ¹⁰ or Mucilage, *Lymph*, *Serum*, *Bile* ¹¹, *Semen* ¹², *Oil* ¹³, *Milk* ¹⁴, *Fat* ¹⁵, &c. ¹⁶ whence these ultimate Branches are no longer call'd Arteries; but are denominated from their respective Juices, notwithstanding they retain the Properties or Affections of Arteries, dividing into lesser Branches, and uniting with corresponding Veins: Hence the Arteries and Veins are not only sanguiferous but also *se-rous* ¹⁷, lacteal, lymphatic, carrying Oil, Water, Spirits, &c. nor can we tell where this Progression, or Division of the Vessels into lesser Series, *terminates* ¹⁸; but we are from hence at least acquainted with the Origin, Progress, Termination, and Office of the lymphatic Vessels; and that there are not only *Veins* ¹⁹ so call'd, furnished with Valves, and conspicuous to the naked Eye, but also Arteries of that Name, destitute of Valves, and render'd invisible by their Minuteness and Pel-lucidity,

lucidity, as we are assured from the *Ruyfchian* Art of injecting.

¹ Different from the Blood at its very first Secretion therefrom, and differing from its own first State by stagnating and exhaling its more subtile Particles.

² This Humour is of three Kinds, either (1.) from the glandular Follicles of the Skin, which is oily; (2.) from the exhaling Arteries, without Violence, which is thin and aqueous; and (3.) from the same Vessels forcibly distended, which is thick and serous, *per* §. 424. Sometimes we sweat out a mere Oil through the Pores of our Skin; and after violent Exercise our Linen is stiff, and stained yellow by the Serum, which has been sometimes follow'd with Blood. Dr. *Sydenham* observes in the Plague, that a slight Sweat proves of no Service; but that a clammy Sweat, holding for four and twenty Hours, expells all the Contagion. In pulmonary Consumptions we also frequently meet with clammy Sweats, which very much resemble the Serum of the Blood.

³ I myself seem to have been the Person who first remarked this oily Matter of the Pores. 'Tis naturally a thin oily Liquor, flowing from simple Glands or Cryptæ under the Skin, thro' the Pores of the Cuticle, which are large enough to admit the Point of a small Needle without making any Wound. It serves to keep the Skin soft and smooth, and appears like an oily Dew upon a Looking-glass, as *Lewenhoec* observes. With this oily and watery Liniment a healthy Man's Face is smeared all over in a Morning when he wakes. When this oily Liniment is totally absterged from the Skin, as in the Hands of a Washer-woman, it cannot then feel the softest Body without Uneasiness.

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ness. When this has been preternaturally condensed and inspissated, it is often expressed from the cutaneous Pores under the Form and false Denomination of Vermicles ; and after it has been obstructed and retained by the Cold, it occasions an itching with Pustules, if not dissolved and discharged by Heat. *Ruyſch* chuses to call the Follicles of the Matter in the Skin rather by the Name of Cryptæ than Glands ; and has found that his ceraceous Injection transudes into them from the cutaneous Vessels. 'Tis a thin Liquor at its first Secretion, but after standing a Week or a Fortnight in the Pores and Cryptæ it becomes inspissated like a soft Wax or Paste in Form of a little Maggot ; and from this Spring arises many cutaneous Disorders.

4 The subtile Fumes or Vapours of *Sanctorius* which exhale from the invisible Pores of the Skin, and which being obstructed by the Cold, elevate the Cuticle into little Tubercles like the Skin of a Goose ; the same being condensed on the Sides of a cold Glass turn to a brackish and limpid Water without any Oil ; and the Vapours of this sort, which are condensed on the Sides of a Looking-glass in the Winter-time, totally evaporate without leaving any Spot or Residuum. Besides these, there are other perspirable Vapours exhaled internally in the Mouth, Fauces Gula, Stomach, Intestines, Bladder, Thorax, Abdomen, Meninges of the Brain, in which is constantly an aqueous Moisture, very different from the Serum and Lymph, and in such a Quantity as to be visible, whereas the external perspirable Matter hardly runs into a sensible Moisture. *Vid.* §. 81.

5 A Humour altogether singular, brackish, and much more saline than the Saliva ; being intermix'd with the sebaceous Paste from the Glands of

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Meibomius, it forms a third Liquor, which concretes into Scales or Lamellæ by Heat, and by an Evaporation of its more fluid Parts frequently acquires a stony Consistence, and hardens into a real Stone; which is a manifest Sign how much the Humours may be changed from their natural State in which they were secreted. This Humour is separated in the Glandula Innominata of *Galen*, and convey'd to the Eye by the Ducts of *Meibomius*, to keep its Tunics moist, bright, and slippery.

⁶ This is secreted in a fluid State like Oil of Almonds, and serves to lubricate the very sensible Membranes of the Tympanum and Meatus Auditorius; but by Contact with the Air it becomes thicker, bitterer, and of a yellow Colour; as all oily Substances do by Heat and Standing, not excepting Cream itself. A Humour that very much resembles this is separated in the Follicles of the Gall-bladder.

⁷ Which is now call'd, almost by universal Consent of Anatomists, the sebaceous Matter: It is thicker than the oily Matter of the other Pores, and may be easily pressed out of its Cells in the Skin behind the Ears, upon the Nose, about the Nipples, Arm-pits, Nates, Pudenda, and such other Parts of the Skin, whose greater Attrition requires such a Liniment.

⁸ The Mucus becoming inspissated by standing and exhaling its more aqueous Parts, appears thicker than the Blood itself, but in its first Secretion it is as fluid as the Tears: It defends the membranous Expansions of the olfactory Nerves within the Nose from being injured by any acrid Particles drawn in with the Air, keeping them moist and fit for Sensation.

⁹ Which is of three Kinds; (1.) the Saliva, very fluid and useful in Digestion (§. 68.) (2.) the

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the thick Sordes of the Uvula Fauces and Parts adjacent, which are indeed thin and watery at first, but become very tough and vitrious in one Night's time, by the Air ; (3.) the Mucus or Phlegm from the Cryptæ of the Larynx and Trachea, by which the very sensible Membranes of those Parts are defended from the Air and its Contents (*per* §. 195.)

¹⁰ An insipid Mucilage resembling the White of an Egg, like which it hardens with Acids and Alcohol ; separated in the Glands of the Joints and Capsules of the Tendons, observed by *Havers* and *Douglas* ; and serving to abate the Friction of the Cartilages on the Heads of the Bones in each Joint.

¹¹ Even this is vastly more fluid at its first Secretion in the Liver, than when it appears in common Ducts, where it mixes with the Cystic Bile. §. 88.

¹² Every Body has a kind of Semen for the Production of its Species ; I cannot, for my own Part, except even Gold and Stones. The Seeds of Vegetables apparently contain the Body and Fabric of the Plant ; and though the Semen Masculinum is fluid, it may even under that Form contain an organised Structure, though invisible.

¹³ This Oil is frequently observed circulating with the Blood in its Vessels, and is secerned throughout the whole Texture of the Bones, insinuating betwixt their Lamellæ, and rendring them smooth and pliable ; and particularly it is deposited in the very fine cellular Membrane within the Cavities of the Bones where it acquires the Name of Medulla.

¹⁴ Which circulates along with the Blood, and is frequently discharged with it by Phlebotomy.

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¹⁵ This is fecerned and deposited in the Cavities of the cellular Membrane, which invests all the Muscles and every individual Fibre of them ; being originally fluid and soft, it by degrees thickens, and only by standing in the Air becomes a hard Fat or Sewet.

¹⁶ For besides those Humours which come under the Cognisance of our Senses, there are many much more subtile, whose Nature our Organs are not acute enough to detect and follow.

¹⁷ The largest of the smaller Arteries are sanguiferous, which before they open into their corresponding sanguiferous Veins, send off lesser Arteries from their Sides, which receive the yellow Serum (*per* §. 245.). In the same manner the ferous Arteries send out laterally some smaller lymphatic ones before they become Veins ; and those lymphatic Arteries will detach a third Series still less, and so on with the several smaller Series, till they terminate in the ultimate or very smallest Series of Vessels in the whole Body call'd Nerves, many of which exhale their very thin Fluid in an insensible Vapour through the Cuticle all over the Body.

¹⁸ No Mathematician will assert that Matter is not infinitely divisible ; at least it cannot be prov'd absurd : Consider what *Lewenboec* affirm of the Semen Aselli (or the Insect call'd a Chessop) which he makes equal in Diameter to a Sphere, the 216,000th Part of the Thickness of a Hair. But Mathematicians demonstrate, that the smallest Particle of Matter may have as many Divisions as the largest ; the smallest Spherule in the Universe has its Hemispheres, North and South Poles and Equator : Whence *F. Malebranch* infers, that the whole System of the World, as large as it extends, may be comprised in a single Point.

¹⁹ The lymphatic Vessels, or Veins of the second Order, all discharge themselves into a common Trunk or Cava, the thoracic Duct (§. 129.) which receives the more subtil Juices of all the reductory Vessels, and returns them into the venal Blood; except those Lymphatics which open immediately into the sanguiferous Veins. But 'tis reasonable to think that these lymphatic Veins are formed not all at once immediately, but by the Union of the several smaller Orders into others larger, which at length form considerable Branches, all opening into the common Trunk of the lymphatic Cava, the thoracic Duct; and therefore the Lymphatics return all the thinner Juices into the thicker venal Blood; both Chyle, Lymph, Serum, Vapours, &c.

§. 247. But then some of the Branches of the forementioned smaller Arteries (§ 245. and 246.) being no farther ramified, but continued strait into the very thin Membrane, which constitutes the glandular *Follicles*¹, do at last open themselves and discharge their Humours into the common Cavity of those Follicles or Cells formed by the said Membrane, in which the Humour is therefore collected, retained, and formed into *glandular Lymph*².

¹ The Circles of the lateral arterial Branches open into the Cells or Cavities of the lymphatic Glands, into which they deposit their contained Humours; and if you press such an arterial Opening or most simple Gland, there comes out first a soft Substance like Paste, shaped like a Vermicle, and upon a stronger Pressure there follows a Drop of a limpid Water. *Peyerus* having cut open and
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cleansed

cleansed a Glandule, observed, by the Help of a Magnifier, that the whole Circumference of the follicular Membrane, was beset with small lymphid Drops sweating out. But you will observe this glandular Fabric in no Part more apparently than in the Kidneys, in which the arterial Extremities terminate in rectilinear Tubes, many of which conjoin into the Papillæ of *Eustachius*, which receive the Urine from the Arteries, and deposit the same into the common Cavity of the Pelvis, in which that Excrement is collected and retained. Such simple Glands, or secretory Tubes and Cells, continued to the Arteries, have been discover'd in a great many Parts of the Body by *Ruysch*, who having happily injected the Skin, found even in that, after removing the Cuticle, a Set of Cavities or Cells fill'd the Injection in the Form of little Worms.

² Here we meet with a Subject much controverted betwixt *Ruysch* and *Malpighi*, viz. whether all the Lymph passës from the secretory Vessels immediately, or whether it is first retained or collected in some Cavities of the Glands, and from thence discharged by the emissary Tube, which we call an excretory Duct. It may be said for *Malpighi*, that the Glands swell in many Disorders from an Obstruction of their excretory Ducts, while the arterial Juices having a free Ingress, distend the glandular Cells into Hydatids, or little round Vesicles fill'd with the accumulated Lymph. To this *Bellini* adds, that intermediate Follicles receiving the secreted Juices, are evident in the Fat or cellular Membrane; in the Kidney, where the Pelvis is the common Follicle or Receptacle of the Urine from the secretory Ducts; and lastly in the Liver, where the Bile is received by the Ducts, and convey'd to the Vesicula Fellea. *Ruysch* on the other hand

hand opposes the Arguments of his Adversaries by Preparations, in which he thinks it very apparent, that his ceraceous Injection passes directly from the Artery into the excretory Duct, without entering into any intermediate Cells or Follicles in its way: For example, in the Kidneys you may easily trace the Injection from the sanguiferous Arteries into their excretory Duct the Ureter. But we may again answer that his Injection fills only the larger Vessels, compressing the smaller, and therefore shews us the Fabric of the Glands and Viscera but in Part.

§. 248. It is also probable that the Nerves of the Glands, dividing and opening into 'em like their Vessels, discharge and mix their subtile Juice with the contained Lymph (§. 247) which by this Means acquires, in some measure, the Nature of the nervous Juice.

§. 249. But there are some of the lymphatic *Arteries*¹ (§. 246.) which discharge their *Lymph*² immediately into the valvular Veins of that Name; and this we call *vascular Lymph*³, which is frequently carried by those Veins to the said Glands, and in a particular manner discharged into their Follicles or Cells, where mixing with the glandular Lymph and nervous Juice, they return all together in a mixt and subtilised State. Upon opening the Abdomen of a living Animal in Health, the Lymph flows swiftly towards the Receptaculum from all the abdominal Viscera; which it also does even after Death, as we are assured from wounding the Lymphatics, which are

in this Action contracted by the Cold, supervening Death.

¹ 'Tis not at all surprising that these Arteries are not visible; for the smallest sanguiferous ones are not so without a Microscope: But the largest ferous Artery must be, at its Origin, six times smaller than a red Globule or its containing Artery, from whence the ferous ones continually lessen as they go. Add to this, that the Tunics of the small sanguiferous Arteries are much thicker than those of the ferous and lymphatics; and then they first convey a red opaque Fluid, and the others a pellucid or limpid Juice, whence it is no Wonder they escape the Sight, even armed with a Magnifier. From these Conditions we should not be able to observe the lymphatic Veins, which are so vastly much larger than the Arteries, if they had not Valves.

² Which, together with the Blood, are the only Humours which concrete or harden; the Lymph containing all the Parts of the Blood except the red Globules.

³ We may reasonably suppose that the returning nervous Juice conduces much to the Composition of this Lymph (*per* §. 292.); for the evanescent Nerves terminating with the smallest lymphatic Arteries compose lymphatic Veins, which are the very smallest that return Lymph, and these Veins uniting into larger Series of nervous Veins, will at last constitute an ordinary or common lymphatic Vein, sizable to the Number of smaller Veins from whence it arises. This vascular Lymph is therefore different from that of the Glands, being thicker and continually in a Circulation.

⁴ This vascular Lymph is returned to the Glands, after it has been discerned and convey'd out
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of the smaller into the larger lymphatic Veins, having Valves, which is the Opinion of *Nucke*, and confirmed by *Malpighi* : So that the vascular Lymph returns to the Glands in the same manner as the Chyle passes to them from the Intestines, by the Lacteals of the Mesentery.

§. 250. This compound lymphatic Humour is in the next Place propell'd through those small reductory lymphatic Veins (§. 249.) to other Glands of the same Nature for the same Purposes (§. 249.) and this partly by the Contraction of their own *fibrous*¹ Membranes with the Pressure of the *Muscles*², and partly by the Pulsations of the adjacent *Arteries*³ : From these last Glands it again Passes to the Receptacle at the Loins, and thence by the thoracic Duct into the sanguiferous *Veins*⁴. And these seem to be the conglobate *Glands*⁵ of the whole Body.

¹ Notwithstanding these Membranes appear so very thin in the lymphatic Vessels, we find they are pretty strong, and exert a considerable contractile Force.

² For when the Muscles are at rest, the thinner Juices, and especially the Lymph, go on but very slowly ; whence we frequently meet with Stagnations, and Obstructions of that Humour, forming a dropical swelling of the Legs, very frequent in those who lead a sedentary Life, or who sit and stand much.

³ The smaller sanguiferous Arteries which run parallel to the Sides of the smaller lymphatic Vessels, in the same manner as the large red Arteries and

Veins usually accompany each other; or as the largest of these Lymphatics, the thoracic Duct, runs by the Side of the Aorta.

4 Either into the Subclavian Vein by the thoracic Duct, or else immediately into the jugular Veins, Emulgents, or the Cava.

5 These Glands are of two Kinds; Some very minute, which separates the Lymph and are invisible (§. 247.); others which are large and conspicuous, like those of the Mesentery, which first receive and elaborate the Chyle (§. 242.).

§. 251. But in other Glands the secreted Juices are disposed of in a different Manner, their Follicles (§. 247.) discharging each their contained Liquor, by their Emissaries, into one *common*¹ Cavity; as in the Cells of the Bones, Sinus of the Os Frontis, Antra of the upper Jaw, Sinus's of the Os Sphenoides under the Sella Turcica, Meanders of the Os Spongiosum in the Nose, the Cavities of the Nostrils and Fauces, with the Lacunæ of the Tonsils; in all which the secreted Mucus is deposited, accumulated and changed. To these we may add the mucous Glands of the Mouth, in the back Part of the Tongue, withoutside and within the Epiglottis, the internal or sensitive Parts of the Nose, and the internal auditory Passages, in the Fauces, Larynx, Trachea, Bronchia, Oesophagus, Stomach, *Intestines*², &c. in all which they may be termed simple excretory Glandules.

¹ The Bones of the Forehead and upper Jaw are in the Fœtus composed of solid and compact Lamellæ,

mellæ, without any Sinus's in them; but in the new-born Infant their bony Plates diverge by degrees from each other, and leave small Caverns, of which that in the Os Frontis will contain about two or three Drams of Liquor, those of the upper Jaw, when pretty large, will hold near an Ounce of Water each, and that in the Os Sphenoides will receive a large Bean. These Sinus's are invested internally with one continued Membrane, in which the Vessels are disposed in a particular and beautiful Order, as the Injection of *Ruyfch* demonstrates. But the whole internal Superficies of this Membrane is not only spread with Vessels, but also every where beset with little rough Tubercles, like small Grains of Millet-seed, which are the Cryptæ or little Cells, upon whose Convexity, over-against their emissary Ducts, the small Arteries are disposed and spent; terminating with their open Extremities inserted into the Cavity of each Follicle, like Velvet or the Down of a Peach, thro' which pendulous or villous Extrenities of the Arteriolæ, *Ruyfch* has thrown his Injection even into the Cavity of the Follicle. Through these villous Ducts of the Arteries a thin and aqueous Moisture distills into each Follicle, where it is retained and inspissated, either by an Exhalation or Absorption of the more fluid Parts, or both, whereby the Remainder is digested into a thick Mucus, differing in Degrees of Consistence in different Parts; but so cohesive in a robust and healthy Body that one Drop will not fall from the other, as Water will. This Mucus draining from the small Apertures of its Follicles, lubricates and defends the very fine olfactory Nerves, which are the most naked and exposed of any, but by this Defence are secured from the Dryness of the Air, and the Acrimony of its contained Particles: But when this Secretion is in-

creased, and the Absorption of its more aqueous Parts impeded by the Winter Cold, it distills in thin, watery, and cold Drops by the Nose, especially in old People. The same Structure is also in the Folliculi of the Fauces, and whole alimentary and aerial Tube; and in the back Part of the human Tongue they appear so numerous and very conspicuous to the naked Eye, after cleansing it, that there remains not the least Room for Scruples or Doubts, nor does even *Ruyfch*, who so strenuously argues for the vascular Fabric, refuse to admit these Cryptæ.

2 All this that has been said is also applicable to the Cryptæ of the Intestines, which have the same Affections. When the follicular Secretion is augmented in the Nose and Fauces, it produces Catarrhs or Defluxions of those Parts; in the Larynx, Trachea, and Bronchia, it produces a pulmonary Catarrh; and, in like manner, a Defluxion in the Intestines, &c. From the Nose this Mucus is discharged by sneezing or blowing, from the Fauces by spitting, from the Wind-pipe by coughing; and from the Stomach, a like viscid inodorous Phlegm is discharged by vomiting, and from the Intestines in the Deposition of their Fæces, &c.

§. 252. There are again other such Follicles or simple excretory Glands, which, having the same Mechanism (§. 251.) discharge their contained *Humours* 1 by proper Emissaries, opening, not internally, but withoutside the Skin; such are those of the external auditory Passages, the external Sides and Tip of the Nose, the internal Entrance of the Nostrils, in the Face and *Cheeks* 2, Neck, Arm-pits,

pits Shoulder-blades, round the Nipples of the Breasts, round the Navel, Hips, Nates, Anus, Perinæum, Pube and Mons Veneris in both Sexes, Scortum, Skin of the Penis, Labia Pudendi in Women, and about the Knees; to which modern Anatomists have given the Denomination of sebaceous.

¹ We before laid it down for a Rule, that every Humour is thin and limpid at its first Secretion; nor are we to except the oily Matter which Nature has supplied to the Skin, to defend it from the Injuries of the Air and the Attrition of other Bodies. This oily Matter, originally very thin, aqueous, and fluid, by exhaling its more volatile Parts becomes inspissated, and of the Consistence of a soft Paste or Wax, call'd by *Morgagni*, and other *Italian* Anatomists, by the Name of sebaceous Matter.

² Inspect the brown and dirty Face of a Country-man, Sailor, &c. and observe with what a vast Number of large Pores the Skin is perforated; each of which has its Sphincter and subjacent Cell or Gallipot full of oily sebaceous Matter, which ought not to be esteemed a Matter coming immediately from the Arteries, since it is collected and changed in the intermediate Follicles. From these large Pores transudes (either by the Heat of the Body, of the Sun, or by external Pressure) a sort of Ointment which makes the Face shine, and upon wiping it off on a clean Cloth, or a Piece of writing Paper, it appears quite oily. By standing long in its Cells, and evaporating its more fluid Parts, it becomes so thick that you may press it out of the Pores in little round Cylinders, like Maggots, with a black Head or dirty End. Its
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great Use is to mollify the Cuticle, and dispose the subjacent Papillæ of the Skin for the Sense of Feeling; for when this Matter has been totally absterged from the Finger's Ends with Soap and Water, as in the Hands of a Washer-woman, we cannot feel even the softest Body without Uneasiness. It also serves to defend the Skin from destructive Friction; in the same manner as Sailors rub their Hands with Tar to prevent their Excoriation when they let Ropes run swiftly through them.

§. 253. Hence the Humours will be various according to the Distance of the *Artery* ¹ from the Heart, its *Situation* ² with respect to the Heart and the Trunk from whence it arises, its different *Complications* ³ and Number of Ramifications before it terminates, the different *Velocity* ⁴ of the Blood moving through it, the Proportion that the single *Branch* ⁵ bears to its Trunk, the different propelling *Forces* ⁶, both external and internal, which discharge the Humours, the different Time of its *standing* ⁷ in the common Cavity or Receptacle, and the various Passages it goes thro', from thence making new Changes, with the different Degree of Absorption or *Exhalation* ⁸ of the more fluid Parts from the secreted Juice; all these Causes, I say, concur to produce that vast *Variety* ⁹ of Humours observed in the several Parts of the Body, from that one common Mass the Blood, whose Particles are thus variously sorted, separated, and combined in a *wonderful* ¹⁰ Manner.

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¹ 'Tis easy to conceive that the Blood which is nearest the Heart will be different in the Motion and Combination of its Particles from that which is more remote, since the last will go on very slowly and retain but little of the Force which the Heart impressed on it ; for to produce the Force which ² will exert at the Distance of ³ from the Heart, will require the Force of 6 at the Distance of 9.

² The Angle which the mammary Artery makes with the Subclavian from whence it arises, is very different from the Angle formed by the Carotid and its Trunk : And the Secretions derived from both are equally different. The most solid, dense, and spherical Parts of the Blood will be carried in a Direction nearest to that of a right Line ; while the other Particles will recede or go off laterally in various Angles, according to their different Solidities, whence will arise a great Difference in the glandular Secretions.

³ These have been demonstrated by *Ruyfch* to be not alike in any two Glands (§. 143. N^o 3.) : Thus the small Arteriolæ of the pituitary Membrane are strait, in the Spleen they form Penicilli or Bunches like Pencil Brushes, in the Kidneys they take a serpentine or vermicular Course, in the Lungs and elsewhere they form Plexus's or Networks, which are different in various Parts, &c. Hence in complicated Arteries the Blood will dilate them more, as striking more directly or perpendicularly against their Sides ; but then the Blood goes on slower in such, because of the increased Friction, when the progressive Motion being diminished Attraction betwixt the Parts will then take place, and they will combine variously.

⁴ The Blood's Velocity is greatest in the Heart and Lungs, and then in the Aorta near the Heart,
from

from whence the Blood gradually moves slower as it recedes farther from the Heart. But the Blood's Fluidity is in Proportion to its Velocity; for by Rest or a slow Motion it becomes thick, but by a swift Circulation it dissolves, and becomes more fluid: Thence *Lewenhoec* observed the Blood moving much swifter and with an accelerated Motion in the small Vessels near the Heart at each Systole; but in the Capillaries of the Extremities he observed the Blood to move with an uniform and equable Velocity.

⁵ The smaller the Branch is, with respect to its Trunk, the more fluid will the Liquor be which flows into it. Some have only regarded this Principle in accounting for the Secretions; but the different Diameters of the secretory Orifices will not suffice alone.

⁶ The more Liquor there is excreted from any Gland, the more there is secreted in it, and the Reverse; whence the Secretions will vary much according to the Causes which increase or diminish them. If a Person drinks a great deal of small Beer, he soon after makes a great deal of aqueous Urine, and then some time afterwards he will void a less Quantity of a more yellow and foetid Urine; therefore by only increasing or diminishing the Impulse of the Blood and nervous Juice, the same Glands will vary their Secretion both in Quantity and Quality. I visit an hypochondriacal Patient who makes yellow Urine for the present, but upon hearing some disagreeable News, a sudden Constriction follows in the Kidneys, and they only secrete a thin pellucid Water: The Blood and the Kidneys are still the same, only the Orifices of the secretory Tubuli are so contracted by the Spasm or convulsive Motion of the Nerve, that they will only admit the thin and aqueous Parts; the Nerves
in

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in the Glands have therefore a great Influence and Concern in their Secretions. Some Glands are indeed pressed and urged on to their Secretions by the Protrusion of the Arteries only, as the Brain, Cerebellum, and spinal Medulla ; and others are influenced by the Pressure of the adjacent Muscles : In the first therefore the Secretion will be more flow and equable, but in the last more accelerated and unequal.

7 If the Nose is continually blowed, the Mucus will not have Time enough allow'd it to thicken, and will therefore be thin and fluid ; but if it stands all Night in its Receptacles, it will, by Morning, become almost as thick as Glew. The Bile of the Liver is thin and mild, but that which has stood some Time in the Gall-bladder is more thick and bitter. Even the Fat is a thin Oil like Water at first, but acquires its Consistence by stagnating. Hence, how easily may we account for the Viscidity of many Secretions from a Principle that has escaped most who have treated on the Subject ?

8 The Semen in the Testicle is, at its first Secretion, as thin as the Tears, but in the Vas Deferens it becomes inspissated into a Gluten.

9 It cannot be properly said that those Humours are, as such, in the Blood, because they are thence prepared and separated by the Glands ; for the Blood contains no acrid Bile, viscid Mucus, bitter Ear-wax, nor seminal Animalcula, &c. but yet it contains the Matter out of which those, and all the other Humours of the Body, are form'd ; which common Matter of the Juices is convey'd from the Heart by the Arteries to the secretory Organs, but does not arrive there in the State we afterwards observe when it has passed the Secretion. Nobody will allow me to give the Name of Ale
to

to Barley, because such a fermented Liquor is prepared from it. The Liquor carried to the Testicles for the Formation of Seed no more deserves that Name till it has passed the Secretion, than a rough Lump of Iron deserves to be called a Sword or Dagger. The seminal Humour is secerned thin and lymphid from pellucid Arteries which do not admit the Cruor, from whence it is transmitted by exceeding minute Tubuli into the Duct of *Higmore*, and passing through the Curles of the Epididymis, and Convolutions of the Vas Deferens, it at length arrives into the common Receptacle of the seminal Vesicles, in a State very viscid and different from what it was originally.

10 'Tis more than a little surprising, even to a wise Man, that the Blood should afford such a Variety of Juices, and that so consistent a Mass should, by the Efficacy of repeated Circulations, yeild so thin a Fluid as the perspirable Matter of *Sanctorius*, which, after being condensed on a Glass, exhales without the least Appearance of any Fæces or Residuum. Nor ought we to imagine the Humours so very different from each other as they might at first appear to us; for Chemistry teaches us that they afford all the same Principles; but they differ in Consistence and the various Proportion and Combination of their Parts.

§. 254. These Causes (§. 253.) varying in different Glands, and acting *separately* or conjunctly, are demonstrated either to our Senses from the Thing itself and the Structure of the Parts, or are from thence deduced with the utmost Evidence that the infallible Laws of Mechanics will admit, assisted with a Knowledge of the Nature of each Humour, which
may

may be easily obtained by every one, since they have them in Possession : We are therefore from hence enabled to understand the vast Number and Variety of the Secretions and Excretions throughout the Body.

† Scarce any one of these Conditions is the same in two secretory Organs, much less is there the same Agreement of several of them in different Glands, if those Organs are compared together. But if those ten different Conditions be variously combined, without any regard to those we know nothing of, they will in Reality produce a thousand Juices all very different from each other. We know, by the Rule of Combination, which directs to multiply the Product of the lesser Term by the next greater, that ten Terms may be combined 362,880 different ways, as all the Words in a Language are composed of the Letters in the Alphabet ; for the Combinations of 2 will be $2 \times 3 = 6$
 $\times 4 = 24$, &c,

§. 255. We have therefore not the least Occasion to imagine set *Pores* †, of various but immutable Sizes and Figures, to account for the Phænomena of Secretions (§. 254.) : It is even repugnant to the Laws of Nature for any such to be in the human Body, or if there were, for them to act in that manner.

† This has been a very ancient Method of explaining the different Secretions ; for *Celsus* describes the Hypotheses of *Asclepias* and *Erasistratus*, explaining them all by invisible Pores, and the Figures of the Particles. The same Method of accounting for the Secretions has been also lately re-
vived

vived by *Cartesius*, and this even with the Consent of several eminent and ingenious Physicians, as *Borelli Gulielmini*, &c. They compared the secretory Organs to Sieves, furnished with immutable Pores of various Sizes and Figures, adapted to the various Particles : Thus the different Glands were reputed to be Sives with Pores, that when the Blood offered itself to them, it only parted with such Particles as were adequate in Size and Shape to each Strainer, whence a Variety of Humours from the same Blood. But this is far from giving a just Solution of the Problem, why different Juices are secreted in different Parts of the Body of a determinate Nature : For (1.) we demonstrate that all the Canals of the human Body are round (§. 212.) since neither Reason or the Microscope could ever discover Canals but what was circular in every Section. (2.) If a secretory Duct should from any Cause acquire a Shape different from a Circle, it would easily change that Shape upon any slight Effort, since its Membranes are so soft and lax as easily to give way. The smallest sanguiferous Arteries of the Body are indeed visible by a good Microscope, though the secretory Ducts are not, which are therefore much smaller than the first (*per* §. 245.) and consequently more soft and yielding than the smallest sanguiferous Arteries, which are themselves so tender as to break or dissolve by touching them ; and when their small resisting Coats give way to the Impulse of the Blood, they are always thereby distended circularly or every way equally alike, since the Blood impells against every Point of their Sides in equal Radii from their Axes. We are also satisfied that the same Viscera always secrete the same Humours, even upwards of fifty Years, the same Bile, the same Urine, the same Milk, in the Liver, Kid-

neys,

neys and Breast; but this could not be done if the Glands change the Figure of their secretory Ducts, for such a Change would confuse the Secretions, and cause Bile to be separated in the Kidneys, Urine in the Breasts, &c. (3.) But even granting immutable Pores of various Figures, and Particles of the Blood of various Figures, it will not follow that some Pores will only receive one kind of Particles and refuse the rest; for whatever be the Figure of a Pore it will admit all sorts of Particles whose largest Diameters are less than its own; and it would even reject its own adequate Particles if they did not present in a certain determinate and favourable Position; as *Pitcairn* demonstrates. We would not however be understood to deny that the Secretions depend very much on the Fabric of the solid Parts; and that the different Structure of the Glands in the several Parts of the Body will occasion different Juices to be separated. If any glandular Part which secerns a mild and innocent Juice to be confused or injured by some external Violence, the Secretion is presently disorder'd, and follow'd with various morbid Symptoms, or perhaps a Cancer, discharging a most acrid and destructive Juice, only from the Defect or Injury of the Solids, by which the Juices extravasate or stagnate, and become putrid or corroding. The Liver being obstructed often petrefies or hardens like a Stone, and secerns Juices of a different Nature from healthy Bile. The Fabric of the secretory Organs therefore transmutes the secerned Juices, as the same Juice of the Earth is diversified by different Plants into various Liquors, so different from each other, as the bitter Aloe or Colocynth, and the sweet Sugar-cane, the fat Olive and the watery Gourd, the soure Lemon, &c. All which Variety of secerned Juices result from the inscrutable

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Mechanism of the animal Vessels or the vegetable Tubes, the different Velocity with which they are propell'd, and the various Combination of their Particles, &c.

§. 256. Much less need we have Recourse to any precarious *Ferments* * in the Glands to solve these Phænomena (§. 254.); whether you imagine those Ferments to be thick and consistent, or thin and fluid, and possessed of a Power to ferment, precipitate, coagulate, dissolve, change, or assimilate; for nobody could ever assign the Cause, Origin, Matter, Place, Mixture, Efficacy, Proportion, Continuance and Effects or Uses of such Ferments.

* The chemical Writers have defined a Ferment, after *Helmont* and *Paracelsus*, to be a Substance which, upon Mixture with another, changes the latter into a different Nature from what it had of itself without the Ferment: Thus Water being mixed with a Mass of fermentable Meal into a Paste or Dough, ferments much sooner and more perfectly by adding a Portion of Leven or other Dough that has been well fermented. These Writers believe, and I was once myself of their Opinion, that no internal Change is wrought in any Body without a Ferment, in the same manner as no vinous Spirit can be procured from any vegetable Substance without a previous Fermentation. The different Secretions are, according to them, made all by specific Ferments lodged in every Gland and Vessel; which Ferments change the newly arrived Juices into their own or a different Nature; thus, for Example, in the seminal Vesicles,

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cles, say they, is lodged a seminal Ferment, which mixing with the Particles of the Blood derived by the spermatic Vessels, changes that Blood into Semen. The Weakness of this Hypothesis is easily seen through; for every Ferment must be fluid on their own Principles, or else they could not mix with nor change the Blood into different Juices. Allowing therefore their Ferments to be fluid, they must mix with the Blood either (1.) by entering the Arteries, which they cannot, since the Blood moves in those Vessels uniformly to all Parts in a Direction that opposes the Return of any Juices: Or, (2.) they must be lodged in the Follicles of the Glands and there mix with the Juices; but then how do they perform the Secretion which is already made? Or (3.) they mix with the Blood in the Veins; but no Secretion is thence made in any Part; whence it follows that Ferments have no Existence in the Body, and that they are incapable of mixing with the Blood, and producing its Secretions.—Add to this, there is no probable Cause or Origin of any such Ferment that can be assigned by any one. If they say those Ferments are coeval and born with the Animal; consider the Smallness of their Quantity that can possibly be lodged in the very minute seminal Animalcule, or its still lesser Glands; and then consider the immense Quantity of Juices secreted in the Body for fifty Years successively, which in the Urine only will at least amount to 22,500 Pounds: You will then readily conclude that there cannot be Ferments enough lodged in the minute Stamina of the incipient Animalcule, sufficient to mix with and change the Juices for so many Years, and not be washed away. If you say the Ferments themselves are originally in the Blood, and direct its particular Juices to enter particular Parts of the Body, we then ask

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what causes the Parts of one Ferment not to act in its kind on Juices in other Parts than its own, and then what becomes of the unactive Ferments in the Parts? at that Rate there will be an infinite Progression of Ferments required to govern each other.

§. 257. Of these more simple Glands before described (§. 242 to 254.), or others of the like Nature, conjoined together by communicating Ducts, and invested with one common Membrane, are formed those compound and larger Glands which we term *conglomerate*¹. These have generally one common Emissary, into which the small excretory Duct of each simple Gland opens and discharges its Liquor, which being collected by the common Duct, is by that convey'd into some larger Cavity. *Of this kind*² are the lacrymal Glandula Innominata of the Eye, the Parotids, Pancreas, &c.

¹ If the parotid Gland be macerated some time in warm Water, and then denudated of its common Membrane, it will appear to be composed of small conglobate or round Glandules in Clusters like Grapes, in opening any one of which you will perceive it furnished with an Artery, Vein, Nerve, and excretory Duct, all constituting one of the least conglobate Glandules; whose excretory Duct unite with that of its nearest neighbouring Glandule, and so with the rest, till all their small Ducts uniting into larger Branches, form at last one large excretory Canal. But if you compare the Fabric of the Liver with this Structure of the Parotid, there

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there will be found a great Uniformity in both; *i. e.* the Liver will also appear to consist of simple Glands (§. 247.) formed into little Bundles, again conjoined into Bunches; as *Malpighi* has asserted in Opposition to *Ruyfch*, who by his Injections endeavours to prove that those Bundles are only Pencil-cilli, or Bunches of Vessels like little Pencil Brushes, detaching secretory and excretory Ducts immediately from the Anastomoses of their Arteries and Veins, without any intermediate Follicles or Cells. I say, without any regard to their different Opinions, the Liver will appear a Congeries of little Bundles like Grape Stones, united into Clusters or Bunches by their excretory Ducts, which at last form the *Pori Biliarii* and *Ductus Hepaticus*. That those Bundles are formed of mere simple Glands is apparent from a morbid Disposition or Petrification of the Liver, which in such a State appears to consist wholly of spherical Bundles like Bunches of Grapes, the Cavities of which are fill'd with a hard congealed Matter, included in every distinct Cell. Hence it follows that the conglomerate Glands are no more than a Number of the conglobate ones uniting their emissary Ducts, and convoluted together in one Membrane, or that the first is a Repetition of the last.

² Hitherto belongs the Thymus or large Gland in Infants, seated in the Top of the Thorax above the Basis of the Heart. From this Gland I was informed that a Duct arose, and went into the Oesophagus towards the Stomach, in a Letter sent me by an *Italian* Anatomist.

§. 258. But sometimes the common emissary Duct (§. 257.) forms a sort of arterial and inflected Canal¹, in which the secreted

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Juice is digested or altered, before it is thereby convey'd, as through an Artery, into the common and larger Cavity (§. 257.) ; of which we have an Instance in *Higmore's Duct*, the Epididymis, and Vas Deferens of the male Testicle, leading to the seminal Vesicles: But sometimes again, the general excretory Duct or Emissary opens immediately into the common Emunctory or *Cavity* ².

* Another Instance of this kind we have in the Ureter, which conveys the Liquor secreted in the Kidney, to a second Follicle or Cell ; viz. the urinary Bladder ; which generally holding ten Ounces of that Liquor, demonstrates its Retention there, by which it will certainly be alter'd from the first State in which it was separated from the Blood. But in the Testicle this Fabric is very surprising, the emissary Canal changing its Diameter three several Times ; for the Diameter of *Higmore's Duct* is larger than that of the seminiferous Tubuli ; that of the Vas Deferens is still larger than the Duct of the Epididymis ; and that of the seminal Vesicles still larger than the Vas Deferens ; there being also a Contraction or Narrowness interposed betwixt the Tubuli of the Testicle and Duct of the Epididymis, betwixt the Epididymis and Vas Deferens, and betwixt the Vas Deferens and seminal Vesicles ; whence if by an Artery we understand a conical converging Vessel, and by a Vein one that diverges, we shall here have thrice an arterial Structure and thrice a venal, betwixt the Secretion and Excretion of the Semen.

² We have a particular Mechanism in the Articulations of the Bones, where the mucilaginous Glands of *Havers* are placed in some Cavity of the Cartilage,

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Cartilage, and discharge their Juice into the common Cavity of the Capsule, which invests the Joint, to prevent the Cartilages from heating by Attrition and giving Pain. But then this Liqueur is never lost or discharged out of the Body, since it has no excretory Duct opening externally ; therefore it must be continually attenuated by the Motion of the Joint, and again returned or absorbed by its proper Ducts or Veins ; but if it stagnates some time for want of Absorption, it becomes acrid and excites violent Ischiadic Pains ; and such Disorders frequently arise from a sedentary or inactive Life.

§: 259. From hence therefore we are assured that the Glands separate not only Water, Lymph and thin Serum from the arterial Blood, but also very subtil, saline, oily and spirituous Parts mixed together with them ; and that all those Juices are either collected and retained, accumulated and changed in certain Cavities or Receptacles for the Purpose, or else propell'd through the smaller Vessels into the minutest Recesses of the Body, for muscular Motion and Nutrition ; and that having performed those Offices, they are either returned by their corresponding *Veins* to the Heart, or else exhaled out of the Body ; and lastly, that the remaining thicker Part of the arterial Blood, from whence they were first separated, is sent forward into the gradually diverging Veins, where mixing with the other venal Blood and diluting Lymph, it at length

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returns

returns into the Heart again, from whence it came.

¹ *Bellini* rightly observes, that the Intestines make up one of the largest and most considerable Glands in the Body, since they are furnished with all the Parts of such a secretory Organ. The first Receptacle of this Gland is the Stomach, into which are convey'd the Liquors of the Mouth, Fauces, Oesophagus, and of the Stomach itself; from whence they pass, after being digested with the Food, into the Duodenum and small Intestines, which make the second Part of this great chylicative Gland; and here they mix with the Bile, Juice of the Pancreas and Intestines: so far therefore in this Part Nature imitates the Follicle of a Gland, into which the Arteriolæ pour their Juice: But this is not all, for the Intestines likewise resemble a Gland in their Separation or Absorption of the Chyle, by the minute Orifices of their lacteal Veins, by which it passes to the Blood, while the more gross and excrementitious Parts are rejected by the Anus. In the same manner we have in all other glandular Follicles both excretory Ducts and absorbing Veins.

§. 260. For which reason (§. 259.) the arterial Blood is the most fluid or *dilute* ¹ near the Heart, gradually thickening in its Progress till it comes to the End of the Artery, where that joins to the incipient Vein; in which Place it will be thickest, most *viscid* ², and apt to concrete; there it therefore requires a Vessel not liable to *Obstruction* ³, with an additional Mixture of *diluent* ⁴ Juices, that is, of the Lymph and nervous *Juice* ⁵ returning to the Heart, after the Performance of their Offices:

fices : But it was necessary for this Dilution of the Blood to be made before its Propulsion into the *pulmonary Arteries* ⁶ ; otherwise it wou'd not be able to pass through 'em and circulate again.

¹ All the Juices of the Body are secerned from the arterial Blood of the left Ventricle ; but the Blood is the thickest of any of our Fluids (*per* §. 226.), and therefore all the Juices thence separated must be thinner than the Blood itself, whose thicker and red Parts are never discharged out of the sanguiferous Arteries in a healthy State, if we except the menstrual Flux. The Blood will therefore be thicker, and less moveable in the Extremities of the sanguiferous Arteries than in any other Part of the Vessels, since all the Secretions of the thinner Parts are made from it before it arrives there. But the Blood is most fluid in the Heart, where it contains all the Sorts of Particles both subtile and gross, very intimately mix'd with each other, which Mixture conduces much to Fluidity in a Liquor composed of dissimilar Parts ; but this will be less in the evanescent Arteries.

² The natural Disposition of the Blood is to concrete or turn solid, and the Fluidity thereof is forced by Motion communicated from the Heart and Arteries ; nor does it continue that fluid State any longer than its Parts are kept from cohering by that Motion with the Addition of some Water (§. 229.) ; but those watery Parts separate from the Blood before it reaches the Anastomoses of the Arteries and Veins, and therefore the blood which there remains will be the most viscid and apt to concrete.

3 Life would be continually in the highest Danger, if the Blood was to pass from the evanescent Arteries into Vessels resisting its Motion; but the Veins continually diverge, so that the thick Blood entering slowly from their Anastomoses or Beginnings, meets with the least Resistance, which continually lessens as the Vessels enlarge.

4 The more fluid Parts of the Blood, which were secreted by the lateral Emissaries from the sanguiferous Arteries, do not totally desert the Blood or leave the Body, but are returned into the Blood again by the Veins, excepting what exhales or is thrown off by the Emunctories. And as the small, red sanguiferous Arteries in many Parts send off yellow serous ones, so the smaller sanguiferous Veins also receive serous Veins arising from their Arteries, and returning the yellow Serum: And such of the thinner Parts of the Blood as do not return this way, are convey'd into the reductory lymphatic Veins, most of which unite into one large Trunk or Cava, the thoracic Duct, by which the Lymph is poured into the venal Blood before it reaches the Heart.

5 Which having performed its Offices returns into the Blood again by the lymphatic Veins (*per* §. 292.); and to this Juice of the Nerves we may add that taken in by the inhaling Veins (§. 126. N°. 4. §. 182. N°. 5. §. 201. N°. 10. §. 295, and 421.) For as many of the smaller Arteries are continued directly into patulent Ducts, which exhale moist Vapours on the Surface of their Membranes, either in the Air externally, or into the Cavities and Interstices of the Body internally; so there are also corresponding Veins which absorb from the Air externally, and from the said Cavities internally, by which Veins those Vapours are returned into the Blood: And that the Air which
every

every way invests us is replete with watery Parts, appears from the Quantity attracted thence by dry Salt of Tartar. Therefore whatever moist Vapours are contained in the Air, they will be absorbed by the inhaling Veins opening thro' the Cuticle externally; but in no Part will they absorb more than in the Lungs, because there those inhaling Vessels are so large, as to transmit the ceraceous Injection of *Ruyfch*, which being forced into the pulmonary Vein, escapes by these Ways into the Vesicles and small Ramifications of the Bronchia.

6 The venal Blood returning from all Parts of the Body to the right Ventricle of the Heart, passes thence from a larger Capacity to a less, *i. e.* out of the right Ventricle into the narrow converging Arteries of the Lungs, where it wou'd stagnate, concrete, and cause a fatal Peripneumony, if it was not more fluid and dilute than in the incipient Veins; in the same manner as Spirit of Nitre being injected into the Veins of an Animal turns the Blood into Grumes like Curds and Whey, as it returns to the Heart; by which Grumes the converging Branches of the pulmonary Artery being obstructed, the Blood's Course thro' that Organ is cut off, and the Animal thereby suffocated. And there are very few Diseases, whether acute or chronic, which prove fatal before they have caused a Peripneumony, or render'd the Blood unfit to pass thro' the Lungs; which it wou'd not be able to do in the healthy Animal, if it was as thick as in the incipient Veins; and therefore the wise Architect has so order'd our vascular Fabric, that all the Juices returning thinner than the Blood, shall be gradually poured into and mix'd therewith in the Veins, before it enters the right Ventricle. But when arrived in the right Ventricle, it there mixes with the highly attenuated Blood of the Heart it-
self

self from the coronary Vessels (*per* §. 183.); and even in the Lungs, the watery Vapours absorbed from the Air in Inspiration, make up for those discharged or exhaled from the Lungs in Expiration: But being by these Assistances enabled to pass thro' the small Arteries of the Lungs, there will be no Danger of its finding a ready Passage thro' all the evanescent Arteriolæ ramified from the Aorta, and which gave the greatest Resistance to the Blood where they form the incipient Veins.

§. 261. From hence we know in what Parts of the Body Life and Health are more immediately, and in the greatest *Danger*¹ of being interrupted; also what Service the *larger*² Vessels and grosser Humours, with the smaller Vessels and more *subtile*³ Humours, are of to render the Body strong, permanent, pliable, and fit for Motion; we likewise from hence understand why the Veins gradually diverge and grow sensibly larger and more *lax*⁴, for the Concourse and Dilution of the Humours, and this before they return into the Heart.

¹ The Circulation will be in the greatest Danger of Interruption (1.) in the evanescent Branches of the pulmonary Artery (§. 260.); (2.) in the Extremities of all the other Arteries, before they open into the incipient Veins.

² This I say in Opposition to the minute Philosophers, as *Cicero* justly calls them, who affirm, That the human Machine might have been more commodiously built than we now find it is, by the most good and wise Creator. Those Gentlemen
place

place the highest Point of Health in the Perviousness of the Vessels, and the Tenuity of the Fluids approaching the Nature of Water : To procure both which, they order plentiful drinking of Tea, Coffee, &c. which, like the Enticement of a Harlot, begin very agreeable, and for the present recruit all the Actions both of Body and Mind, and excite them to a brisk Activity ; but then, like *Venus*, they leave fatal Effects behind them, a Weakness of the whole Habit, an Inactivity of the Juices, a Relaxation and Weakness of the Fibres, and the whole Train of hypochondriacal Disorders, extending themselves even to future Generations.

To enable us to judge how wisely the Creator has formed some of our Juices of a large or gross Texture, and others of them diminishing in several lesser Series, we ought first to consider, that in the human Machine there is required one Spring or Principle of Motion by which all the Juices may be propell'd to the several Parts where they are requir'd ; were there to be more Springs of Motion than one, they might be charged with being superfluous, or with disturbing the Oeconomy by the different Degrees and opposite Directions of their Forces, which wou'd endanger the whole System ; for we even find generally but one Heart in Monsters that have two Heads or two Bodies. As but one Heart is necessary, so it is required that all the animal Juices to be moved thereby, pass into and mix together in its Caverns or Ventricles ; which we find is admirably executed, insomuch that there is no one Humour moving in the whole Body but what was lately mix'd with the Blood in the Heart.—It was necessary for the moving Power of this Spring, the Heart, to be very considerable, that it might overcome all the Resistances op-
posed

posed to it (§. 215.) ; and for the same Reason it was necessary for the Vessels next the Heart to be strong, that they might sustain the Impetus of that Muscle, and propell the Blood by their own Contraction when that of the Heart ceases. And as the Force of the Heart hardly extends itself beyond the first Series of Vessels, *i. e.* sanguiferous Arteries and Veins, it follows that the more subtile Juices of the Blood must be propell'd thro' the several smaller Series of Vessels by the Force of the sanguiferous Arteries. Thus the Force of the Heart will be communicated to the sanguiferous Arteries by the Blood ; and by the Contraction of the sanguiferous Arteries, such Parts of the Blood as are less than the red Globules will be propell'd into and thro' the smaller Series of lymphatic Arteries. But if the red Parts of the Blood were not larger than the yellow serous ones, it would all be forced into the lateral serous Arteries instead of returning by the Veins, and there stop, not being able to enter the lesser Lymphatics ; another Consequence of which would also be a Collapsion of the Anastomoses of the sanguiferous Arteries and Veins, thro' which Blood passës to the Heart naturally in continued Threads.

But the smallest lymphatic Globules cannot be produced immediately from the larger red ones, any more than the intermediate Lamellæ in the Albumen of an Egg can pass immediately into the fine crystalline Colliquamentum that first nourishes the Carina ; whereas by Incubation for some Days, all the albumen is so attenuated as to pass into the Substance of the Chick. There are therefore intermediate Series of Arteries, which carry Liquors consisting of Particles less than the red Globules, and larger than the smallest lymphatic ones ; and these we call serous Arteries. Here again

again the serous Globules are required to be of a Diameter larger than to enter the lateral lymphatic Arteries springing from the serous ones ; otherwise those last wou'd be deserted, or totally emptied of their Fluid : And Experience demonstrates, that those serous Globules are each six times leis than red ones, (*per* §. 226.) But the serous Globules are far from being the smallest in the Body ; for the next Series of Vessels, or the largest Lymphatics, carry Spherules each six times less than the serous, and thirty-six times less than the red Globules : so that the thinnest and finest Juices in the Body arise intermediately from the gross Blood, thro' many Series of decreasing Vessels, lest if the Blood consisted entirely of the smaller Spherules it wou'd be immediately consumed, and none left to return into the Heart. Hence in Men who have lost a great Part of their Blood by a Wound, and being thirsty have indulged themselves with drinking large Quantities of thin Liquors, we see an universal Dropsy is speedily the Consequence. And for the same Reason frequently arise watery Tumours from an Obstruction of the Vessels which then only admit the aqueous Parts, which pervade more easily than others in the Blood, which stagnating in its proper sanguiferous Vessels, the aqueous Parts readily pass into the lateral Vascules. Lastly, we often observe the Blood so far divided and broke by many Causes in pulmonary Consumptions, that it runs out of the Body in Sweats even to the Destruction of the Patient. But on the contrary, if the healthy serous and red Globules combine into larger, as they often do in acute Fevers, then the Blood will be all confined in the sanguiferous Vessels, and the serous ones will be either empty, or stuffed with too large Globules, by the increased Action

on the sanguiferous Artery, whence Inflammation, a Loss of the Secretions, &c.

3 We have before observed how necessary the thicker red Parts of the Blood are, since they alone generate its Heat (*per* §. 220.); but it is also requisite for the Blood to contain other smaller Globules adapted to the several lesser Series of Vessels. The human Body being built not to stand still, but for various, perpetual, and very swift Motions, it was necessary it shou'd consist not of one continued or solid Mass, incapable of yielding, or inflexible to a small Force, but of many small Fibres moving easily by the Sides of each other, in their moveable Parts, and sustained or secured by the ligamentary Insertions of their other Parts. But these moveable Fibrils must be hollow (*per* §. 440.) or else they cou'd not be nourished: Therefore it was necessary for the Body to be made a vascular Compages, not only furnished with Vessels of several Orders down to the minutest, but also with Juices of a determinate Consistence and Texture adapted to each Series of Vessels, in order to pervade them. It was also necessary for the Parts of some Juices to be so far attenuated, as to exhale in the Form of a Vapour betwixt the Fibres and Interstices of every Part, to distinguish and divide them from each other; and this we see is done, not with Water, for that wou'd be too sluggish, and apt to form dropscical Tumours, but by a moist lubricating Vapour.

4 It was necessary for the Veins to be lax, that they might be easily fill'd by the small Impulse of the lesser Arteries, and afford room to retain or store up the Blood to supply the Heart; they ought also to be capacious for receiving the new Chyle, and to allow for the Blood's Rarification by Motion, &c. And the Figure of the Veins ought to be that of a diverging Cone, that the Blood might
pass

pass easily thro' them as upon an inclined Plane, and so pass to the Heart without Resistance, (*per* §. 260)

§. 262. Some Glands however seem to have a different Fabric and Contexture (than at §. 257, 258.) ; so¹ that the Artery sometimes conveys the thicker Parts of the Blood which it carries, by open Anastomoses from the Artery into the fellow Vein ; and then Proceeding alone, complicated and folded in its Course, at last distils a particular Juice from the Mouth of its last Extremities into a common Receptacle ; which Juice, tho' different from the Blood, is nevertheless prepared and derived from thence. See *Leal Lealis* on the spermatic Vessels, *apud Eustach. Opusc. Anat.* And indeed whoever considers that the Stomach, as a hollow Gland, has its Emissary, the small Intestines, variously disposed, for changing, dissolving, mixing, and separating the Chyle ; and who also considers the same Difference of Fabric in the Testicle, Epididymis, Vas Deferens, seminal Vesicles, Urethra and Prostate, they will perhaps not at all doubt but the same Variations may also obtain in the smaller Glands. Who can pretend to say what *opero*²se Fabric may be concealed in the Cortex of the Brain and Cerebellum, spinal Medulla, &c. ?

¹ The Passage of the Blood by Anastomoses from the spermatic Artery into the Vein was described after *Galen* and *Eustachius* by *Leal Lealis* ;

and *Raw*, who strenuously opposed this Communication, found the same to be true by the Experiment of Injection, made at my Request. And we have lately had an Account given us of a very evident Communication in the spermatic Vessels, inserted by Dr. *Mortimer* in *Philos. Transact.* N. 415. in which Case the Injection passed from the spermatic Vein into the Artery, and from the Artery into the Vein. But notwithstanding all this, we must frankly acknowledge that Accounts have been sent us from *England*, and elsewhere, and that Experiments have been made with Injections by the most diligent and expert Anatomists, assuring us, that the arterial Branches of the Spermatic wreathed in and out, do only adhere to the Vein, without at all being inserted into it, or making large Anastomoses therewith. But this we may depend on, that the spermatic Artery intermixing itself with the Vein, in a Process of the Peritonæum at some Distance from the Testicle, does, at its Arrival there, disperse into lateral Branches, terminating in small visible Anastomoses with the corresponding lateral Branches of the Vein, into which the red Parts of the Blood are transmitted, while the serous and lymphatic Parts are carried by the smaller Arteries into the Testicle, whose glandular Pulp or Substance is therefore pale and bloodless, while its including Tunics are abundantly spread with small Blood-vessels; so that while the Membranes are plentifully supplied with Blood, the Pulp of the Testicle is supplied with pellucid Juices by Arteriolæ much smaller than the sanguiferous, and into which the *Ruyfchian* Injection will not enter. The same Structure is also observeable in the Cortex of the Brain, and perhaps the same Mechanism may be repeated in several other Viscera, where our Eyes and Microscopes are not able to penetrate.

2 Thus

² Thus have we in general consider'd and determin'd the Laws and Circumstances of Secretion (§. 253.) ; but we have reason to suspect that there are many Variations and Particulars not yet discover'd to us : For we even know in reality that Secretions may be made from a Vein, by what we observe in the Porta of the Liver from whence the Bile is separated. The diligent Anatomist *Raw* formerly suspected that the medullary Oil of the Bones was secreted from the small Veins ; and it is certain that the oily Cells have a very open Communication with the Veins, by the speedy Return of their Contents that way : We are therefore not yet clear in the Business of all the Glands and their Secretions ; and there are probably many Artifices concealed from us in this Branch of Nature, which we have not so much as suspected or thought of.

§. 263. Since therefore *Hippocrates*, *Wepfer* and *Malpighi* have, from an accurate Survey of the Cortex of the Brain, compared its Structure to that of a Gland, it is evident they saw so much Similitude bewixt the Fabric of this Part and that of other Glands, that they made no doubt but the Cortex of the Brain was truly glandular : *Malpighi* has even pronounced the Glandules of the Cortex to be of an oval Figure, and somewhat angular by their Compression on each other ; and that the small ones being disposed in Curves and attached together, form larger oval Glandules, which again combine into still larger ; which last being collected and disposed in Convolution like the Intestines, immediately compose the outer Part of the Cortex ; so that the smallest

Branches of the carotid and vertebral Arteries being here convoluted into the Structure of a Gland, might distill from an infinite Number of their very minute Ducts or Mouths, the most subtile Parts of their Blood, into their proper Follicle or Cell, to be convey'd from thence into the Emissary, while the remaining grosser Parts of the Blood are returned by the small Veins into the Sinus's. See §. 236.

§. 264. This Opinion of *Malpighi*¹ is favoured by the *Eye*² and *Microscope*³; by the Brain appearing to divide itself into little Heaps, like Glands, after it has been *boiled*⁴; from the distinct Appearance of the Furrows betwixt those round and prominent Heaps, by pouring *Ink*⁵ on the Cortex, and then wiping it off; from the morbid Concretion of the Cortex, into a stony Substance shaped like a *Mulberry*⁶: To these we may add the Degeneration of the contused Cortex into a sort of glandular *Fungus*⁷, sprouting up through the Hole or Fracture of the Cranium, and the evident Change of the same Part into *Spherules*⁸ or Hydatids from a dropsical Disorder; all which seem to prove that this Part of the Brain has the same Fabric with other Glands, only much more subtile or minute.

¹ Who holds that the Brain is composed of Lobes, which are again made up of Lobules, and those last of Follicles, upon the proper Membranes of which the small Arteries are distributed, and distill the Spirits or most subtile Juice of any in the Body

Body into the Cavities of the said Follicles, from whence the Spirits flow by their proper Emissaries, the nervous Tubuli or Fibrillæ.

² Such is the Colour, Humidity and pulpy Softness of the Brain, and so near a Resemblance has it to the Fabric of other Glands, that it was ranked among those Parts by *Hippocrates* in his Book of Glands. But it does not follow, that because the intermediate Substance of the Brain betwixt its Arteries and Veins appear glandular, that therefore it is composed of Follicles ; since we know that many Glands are composed of mere lateral Vasculæ in many other Parts of the Body, and therefore the same Mechanism may obtain here.

³ Tho' M. *Lewenboec*'s Microscopes were not very well adapted to examine pellucid Objects, he cou'd nevertheless observe, with his last or most convex Lenses, that the Brain consisted of round, splendid, and as it were oily Corpuscles, resembling little Glands. But *Malpighi* preferr'd the Microscopes made in *England* by the expert Optician *J. Marshall*, ingeniously contrived with three or four Lenses, as described in the *Philosophical Transactions*, and in *Harris's Lexicon Technicum*. But *Lewenboec*'s Microscopes were single, consisting of but one Lens, permitting the Distance of one Semidiameter of the Lens betwixt the Object and Glass ; which Distance is too inconsiderable in the smaller Lenses to give the Object Light enough to be clearly viewed by the Eye of the Inspector. *Malpighi* therefore used the double Microscopes from *England*, by which he cou'd percieve the small Arteries of the cortical Substance terminate in very minute Circles, their Intervals appearing to be fill'd up with little Grumes or round Bundles ; and most of the Learned after him either saw, or imagin'd they cou'd see these round glandular Cor-

puscles in the Cortex, which were in reality no more than its pellucid Substance terminated by the Blood-vessels on every Side.

² This Artifice was used first by *Malpighi*, and then by *Vieussens*; which last boiled the Brain in Oil for the Space of several Hours, because boiling Oil is thrice as hot as boiling Water, and therefore makes the Brain much harder by boiling; after the Pia Mater had been first separated from it on all Sides, he perceived the whole Surface of the Cortex beset with little round Tubercles or Inequalities: But it must be consider'd, that the Parts of the Brain do not retain their natural Disposition after they have been thus boiled, so that we can rely but little on the Experiment, which at most only demonstrates, that there are little Portions of the Cortex distinguished from each other by the Pia Mater, which deserts or shrinks from them by boiling.

³ *Malpighi* having removed the Pia Mater, poured Ink upon the unequal Surface of the Cortex of the boiled Brain, and upon wiping it off, there remained black Lines or Furrows like the Marshes of a Net, betwixt which appeared white oval Corpuscles protuberant; but *Ruyfch* easily demonstrates, that the Ink thus descends only into the Sulci formed by the Vessels, and therefore only show the Course of the small Vessels contracted.

⁴ *Wepfer* has an Observation on some Parts of the Brain petresied or formed into a stony Substance full of little Eminencies like a Mulberry; which seems to be a strong Argument in Favour of *Malpighi's* Notion of the Brain being glandular: For a Juice or soft Substance does not assume any proper Figure of its own by Concretion, but upon petresying it takes the Shape of the hollow Cavity or Receptacle in which it was confined. Therefore

fore from the Appearance of the petrefied Juices in the Cortex of the Brain, it seems to follow that the Humours thus changed retained the Figure of the glandular Follicles into which they were fecerned before Petrefaction; which Follicles, thro' originally invisible from their exceeding Minuteness, are yet by this morbid Indisposition distended and render'd conspicuous by the congested Matter.

⁵ When the Dura Mater has been wounded by any Accident, the Brain usually protrudes itself thro' the Opening in that Integument, and forms a sort of fungous Excrescence upon the Lips of the Wound; so that the narrow Part of the Cortex coming through the Dura Mater is like a Stalk, but the external Surface of the Fungus is beset with rough Tubercles like little Buttons, or the Heads of Mushrooms. But these excrescent Tubercles are thought to be the glandular Portions or Follicles of the Brain distended, enlarged and supported by their Peduncles or emissary Ducts, probably after the manner of Grapes. But in effect, these Tumours show no more than that the arterial Fluid has a great Nifus or Impulse thus to protrude Matter, and distend the Parts; and it is certain that a vascular Fabric or Compages may be equally distended by that Force as a glandular Structure.

⁶ Another cogent Argument in favour of the glandular Fabric of the Cortex, is the Appearance which it makes in an Hydrocephalus, when the Sutures separate spontaneously from each other; and after opening the Cranium, removing its Integuments and inspecting the Cortex we frequently observe it beset with little Vesicles or Hydatids, distended with a pellucid and resplendent Lymph or Serum; and upon opening each of them by Puncture with a Needle, they severally discharge

a single Drop of Liqueur, without communicating with each other. This Liqueur probably arises from the moist Vapours, which are naturally very subtil, being redundant and collected into a sensible Water; but *Ruyfch.* has, in his latter Preparations demonstrated, that the cellular Membrane is insinuated all over the Brain, betwixt the Tunica Arachnoides and Vessels of the Pia Mater, in which cellular Fabric he has sometimes observed an oily Fat contained; and therefore he attributes the Appearance of those Hydatids to a Distention of the Cells with an aqueous Lymph. (*Vid.* §. 82.) Even every Part throughout the whole Body is surprisngly invested with communicating Cells, which become very turgid and conspicuous by Distention either with an aqueous or oily Humour from the Blood; and wherever this cellular Expansion is continued there the Parts are liable to dropical Tumours or Distentions. A Man who had his Legs swell'd to a most monstrous Size by the Distention of this Membrane, happened to break his Shins by accident, so as to wound this cellular Membrane; in consequence of which all the distending Water ran out, and left the Skin collapsed about his Legs, that one might have imagined them invested with Bags. I therefore make no doubt but that as this Membrane is extended with all the Vessels and Fibres of the other Parts and Viscera, so it is likely to be in the Cortex of the Brain, where it may form Hydatids as in the other Parts.

§. 265. But whether the ultimate little Branches of the cortical Vessels be directly continued into the fibrous Substance of the Brain (§. 269.), as *Ruyfch.* endeavours to prove
by

by his Preparations, cannot be determined by any *valid*¹ Argument; because those evanescent Vascules are too minute to be any way perceived by the Eye, and even *Ruysch*, by his most accurate and fullest Injections of this Part, could never tinge the medullary Substance of the Brain red, but it always retained its native white Colour (*per* §. 262.). It must yet be confessed that this Opinion of *Ruysch* seems very probable for many *important*² Reasons, which we shall hereafter mention (§. 269. & *seq.*); but which ever Opinion takes Place in the cortical Fabric of the Brain, whether that of *Malpighi* or *Ruysch*, the Effects or Consequences will be found nearly the same in both.

¹ We before observed what might be objected to the Preparations and Experiments of *Ruysch* in §. 236. ; since it appeared that a very great Part of the most tender Fabric in the Cortex was that way destroyed, and only that Part left entire which lay next the Pia Mater, and was fill'd with the durable ceraceous Injection, which he could never force into the ultimate Series or smallest Branches of the Vessels; and therefore it cannot be thence inferred that there are no intermediate Glandules betwixt the Extremities of the Arteriolæ and the Beginning of the Nerves; he demonstrates plainly that there are infinite Numbers of small Vessels in the Cortex, but by no means proves there are nothing else but Vessels.

² There are in short such probable Reasons advanced for the Opinion of *Ruysch*, that I must at length come into his Notion entirely; for if there
were

were any of *Malpighi's* intermediate Follicles betwixt the evanescent Arteries of the Cortex and the incipient Tubuli or Fibres of the Medulla, they would unavoidably intercept and hinder the arterial Pressure of the Juices into the Nerves, by which the whole Mass of nervous Fluid would be retarded in its Passage through the Medulla of the Brain ; whence must follow dangerous Consequences, even fatal to Life, since Life immediately depends on the free and uninterrupted Influx of the nervous Juice from the Brain and Cerebellum. Such a Mechanism is also repugnant to the wise Conduct of Nature which she uses in other Parts, where we observe the secretory Ducts continued immediately from the Arteries, and conveying their Juices thence from the Blood without any Delay ; whereas in all Glands, where Secretion is performed in Follicles, the Juices are not secerned and dispersed equally, but there are a sort of Paroxysms or Fits of an increased and diminished Secretion, as we observe in the Bile, Semen, Urine, &c. But there are no such Fits of an increased and diminished or irregular Secretion in the Brain, and it would be dangerous for such to be there. We know the Follicles propell their contained Juices by a membranous Contraction, and not by the protrusive Force of the Arteries ; and that their Contraction is not constantly but at Intervals, and therefore *Malpighi's* Doctrine would infer alternate Repletions of the Nerves from their Follicles, so that we should thus be sensible and insensible at Intervals. The Substance of the Brain so very exactly filling the whole Cavity of the Cranium, is also a sufficient Evidence there can be no Accumulation or Contraction in any Cells of the Cortex ; and if there were intermediate Glandules in that Part, we should hardly suffer such an Eclipse or sudden Loss of
all

§ 267. *Cortex of the Brain.* 267

all the Functions depending on the Brain and Nerves, upon removing the arterial Pressure of the Blood from the Encephalon, as in bleeding, &c. But we experience that this Pressure of the Blood from the Heart and Arteries is no sooner destroyed or impaired, but that very Instant all the Functions of the Brain cease, and return again as suddenly when that arterial Pressure is restored. Lastly, we hardly ever meet in the Brain, even of 80 Years standing, with those Disorders so frequent in other glandular Parts, which have a much stronger Fabric.

§. 266. The Extremities then of those smallest arterial Branches (§. 265.) or of those little glandular Follicles (§. 263.) send out small white Threads, which, becoming more compact, unite and form the Corpus Callosum and Medulla of the Brain, which last is closely invested by and connected to the *Cortex* * or cineritious Part, both in the Brain and Cerebellum; so that wherever the cortical Part terminates, there the callous or medullary Part always begins.

* Which ought not to be thought as deep as the Sulci of the Brain, in which the Pia Mater inserts itself; for I have frequently demonstrated that the whole Cortex hardly ever exceeds the Thickness of a Finger's Breath.

§. 267. But which ever Way these Parts communicate, the cortical Machine is so accommodated or adapted to the medullary Substance, that it adheres not only to the
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Surface both of the Brain and Cerebellum, but also to the outermost Appendices of the Corpus Callosum, and to the Ventricles, and is even *continued* ¹ with the spinal Medulla, and the oblong Tract or Portion thereof, which is without the Brain ; but so that in this latter, the *cortical* ² is included in the medullary Part, and intercepts a sort of Sinus in its middle, in which a vast Number of small Arteries are ramified down the whole Extent of the spinal Medulla.

¹ The cortical Substance is, not only continued down the middle of the whole spinal Medulla, but also abounds there more or less in Proportion to the Number of Nerves sent out ; whence it is too that the spinal Medulla is very thick even at the Os Sacrum, where one might imagine it must have been exhausted by detaching so many and large Nerves in the Way,

² It was altogether necessary for the medullary to include the cortical Substance in the Medulla Spinalis ; because the medullary Fibres arise every where directly from the cortical ones ; but if the cortical Substance had been placed withoutside the Medullary, then the Fibres of the last must have concurred towards the Center, and there have met ; but they are designed not to meet but to be sent out in Nerves, and therefore they would then have perforated the Sides of each other, *i. e.* the medullary Fibres of one Side forming Nerves, would send them through the cortical and medullary Substance on the other Side of the Spine, so that the Nerves of the right Side would have arisen from the left, and the Reverse. To prevent these Inconveniences and Embarrassments Nature has inverted

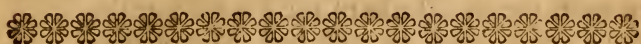
verted the Fabric of the Brain in the spinal Medulla, placing the cortical or cineritious Substance withinside, and the medullary Substance without, that the Fribes of the last might be collected like the Radii of a Circle, and formed into Nerves. *Vid.* §. 237.

§. 268. So that wherever this Compages (§. 263.) of invisible Arteries and corresponding *invisible* Veins is continued, throughout the Encephalon or Brain and its Appendages, there we also of necessity meet with this cortical Substance, as well in the Recesses, Convolution, Divisions, Interstices and Appendices, as in the external Superficies thereof next the Cranium.

* No sanguiferous Vessel was ever observed in the cineritious Part of the Brain; none of those Arteries belong to it which go down perpendicularly from those of the Pia Mater, which are distributed in the Sulci of the Brain. Nor has the cortical Substance any sanguiferous Veins, as *Raw* and *Drelincourt* have observed; and yet if we consider what a vast Quantity of Blood is brought to the Brain by the Arteries, the greatest Part thereof must be returned by the Veins of the Pia Mater into the Sinus's, since the Arteries do not send any of their Blood immediately into the Sinus's (*per* §. 234.) In a Man that is hang'd the Blood finds Admittance to the Brain by the carotid Arteries, which are deeply seated, but is prevented from returning again by the Veins, which, lying near the Skin, are compressed by the Rope; thus all the Arteries and Veins of the Pia Mater will be distended with Blood as if they had been fill'd with the Injection

jection of *Ruysch* ; but notwithstanding the Sinus's and Veins are thus turgid and distended, there is not the least Redness to be observed in the Substance of the Cortex ; and therefore it follows, that all the red Blood circulates only from the sanguiferous Arteries into the sanguiferous Veins of the Pia Mater, whence it passes into the Sinus's of the Dura Mater. But though there are no sanguiferous Vessels in the Substance of the Cortex, yet there are smaller ones which convey Juices thinner than the Blood, as we are assured from the Nutrition and Growth of this Part which enlarges in Proportion to the rest of the Body, which could not be effected without a Distention by the Juices impell'd by the Heart ; and the Truth of the Fact is confirmed by all the Evidence that Reason and Analogy can afford ; and therefore this seems to be the genuine Fabric of the Cortex : *Viz.* from the sanguiferous Arteries of the Pia Mater arise (1.) sanguiferous Veins which open into the Sinus's, and (2.) serous Arteries which admit all but the red Parts of the Blood, and again send off smaller lymphatic Arteries, and corresponding serous Veins, so that the serous Artery transmits its grosser and yellow Parts into serous Veins, and the more subtil and pellucid into lymphatic Arteries ; which again send out many other smaller Series of lymphatic Arteries, till the last Series of them terminate in the nervous Tubuli or medullary Emissaries of the Brain. The infinite Number of Anastomoses or Communications betwixt the Branches of the several Series or Strata of pellucid Arteries in the Cortex, is the Reason that this Secretion and the Action of some of the Nerves does not cease when Part of the cortical Substance has been suppurated or otherwise destroyed ; because the innermost Strata of Arteries are still supplied with their Juices by the lateral Anastomoses

naftomoses or Communications of their Branches ; so that if the Medulla of the Brain be not totally deprived of all its cortical Substance in any Part, the Secretion will still continue there, and supply the medullary Tubuli, notwithstanding the Pia Mater and superior Vessels are destroyed or suppurated. These Anastomoses of the Vessels seem to be disposed in the manner of the Circulus Arteriosus Willifianus.



Of the Medulla of the Brain.

§. 269. **S**INCE therefore Part of the Medulla arises from every Point of the Cortex, the former must of necessity be very fine and tender at its Origin ; but conjoining in its Progress or Descent with the other neighbouring Tubuli like itself, it becomes gradually more *large*¹, compact, and visible, so as to constitute the Medulla and Corpus Callosum of the Brain, with the Crura of the Medulla oblongata, the Thalami of the optic Nerves, the Medulla oblongata and its Crura, Productions and *Protuberance*², with the Medulla of the Cerebellum, and its Continuation into the Medulla oblongata of the Brain, which, *uniting*³ herewith, forms the Corpora Pyramidalia and Olivaria, and then extends itself down in the spinal Medulla, even to the second Vertebre of the Loins, where it is divided by Integuments from the Pia Mater into
distinct

distinct Nerves, which are dispersed from this last Head or Origin of them, like a Horse's Tail, as it is also named; and lastly, it is from this medullary Substance, lodged in the Cranium and Cavity of the Spine or Chain of Vertebræ, that all the *Nerves* ⁴, in any Part of the Body whatever, take their Origin.

¹ We are not able to discern one of the smallest or most simple Fibrills of the Medulla arising from the Cortex, even by the best Microscopes; and the little sanguiferous Arteries, which are by many Series larger than the Tubuli or Fibrills of the Medulla, cannot be perceived by the naked Eye: But when many of those minute Fibrills of the Medulla conjoin into a Fasciculus or Stratum of a hundred or a thousand, &c. we can then perceive them under the Form of the medullary Substance of the Brain.

² The Creator seems to have framed the Brain with so many Eminences and Convolutions, that the cortical Substance might have the greatest Extent of Surface, and that the greater Number of medullary Fibres might arise from it, and be from thence distributed in distinct Orders or Classes, without interfering together in their Courses.

³ There is not one, even of the smallest Nerves, which arises immediately from the cortical Substance either of the Brain or Cerebellum, nor even from the medullary Substance of either of them separately; but the Nerves all arise from the Medulla oblongata formed by the Conjunction of the Medulla of the Brain and Cerebellum.

⁴ We ought not strictly to confine all the Nerves to so narrow Bounds as forty Pair only; for in each Fasciculus or Nerve of those Pairs, are
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contained an infinite Number of other Nerves distinguished by their proper Membranes, and thence dispersed into all the solid Parts of the Body, which they constitute. So that in the human Body, as the incomparable *Sydenham* wisely observes in treating of hypochondriacal Disorders, we meet with two Systems or Principles of Motion combined together; *viz.* (1.) the external or vascular System, on which Life depends; and (2.) the interior nervous System for Sensation, &c. of both which Systems the whole loco-motive Animal is composed.

§. 270. But that the Filaments which compose all these Nerves, were originally separate and distinct from each other in the Brain, notwithstanding they seem there conjoined into one continued or compact Mass, will be sufficiently apparent to any one who considers (1.) their Origin, Composition, and Progress from the *distinct*¹ Portions of the Cortex; (2.) their Appearance in the Brains of *Fish*², Hares, Sheep, and Oxen, either crude or boiled; in which the medullary Fibrills are manifestly observable like depressed Cylinders disposed in Striæ, by the Sides of each other, like the Teeth of a Comb; (3.) the small *sanguiferous*³ Vessels insinuating betwixt the medullary Fibrills, and making a manifest Division or Separation of them; (4.) the Inversion or Interposition of the Cortical within the ambient *medullary Substance*⁴ of the Medulla Spinalis; (5.) the Course of the white Fibres dispersed through the middle of the cortical Sub-

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stance,

stance, which is *continued* ⁵ in the Back-part of the spinal Medulla before its Egrefs from the Cranium, and are also observable in the Sides of the same spinal Medulla, near its Origin within the Cranium, but are best seen in the Appendices of the Corpus Callosum and in the Cerebellum itself; and (6.) lastly, the Collection and Distribution of these medullary Fibrills, first into the Medulla Oblongata, and then into all the *Nerves* ⁶ of the Body.

¹ The cortical Substance, we observed, is variously disposed in distinct Convolution, and terminates internally where the medullary Fibrills begin; whence it follows that the Combination of medullary Fibres must have arose from distinct Portions of the Cortex, *per* §. 266.

² The medullary Fibrills appear most distinct in the Brains of such Animals as have a very swift Motion of their Muscles, and in those Brains they are observed in Striæ, or disposed like the Teeth of a small Comb, as *Malpighi* has described them in Fish.

³ If you divide a Portion or Convolution of the cortical Substance transversely, after the Brain is injected, there does not appear so much as one red Spec or divided Blood-vessel; but if you divide a Portion of the medullary Substance in the same manner, you will perceive innumerable red Points betwixt the milk-white Fibres of the Medulla; which red Points are divided Vessels, which come down perpendicularly from the Pia Mater, where it insinuates betwixt the Gyri of the Cortex, and are not dispersed in a reticular manner among the Substance of the Medulla, but seem to run parallel with the medullary Fibres, to communicate Warmth.

Warmth to this coldest and most exanguious Part of any in the Body : But these Vessels must of Necessity divide and distinguish the medullary Fabric into Fasciculi or Portions ; and in the same Manner we observe the optic Nerve is perforated in its Center by a small Artery of its own, which divides the medullary Substance of that Nerve.

4 The internal or cineritious Substance of the spinal Medulla, appears (by the *Ruyfchian* Art of injecting) all over beset with red Vessels, like the Cortex of the Brain, with its Pia Mater. This vascular Plexus in the midst of the spinal Medulla is the Seat of a Disorder similar to the Hydrocephalus, being a Dropsy of the internal cortical Substance of the spinal Medulla, so often fatal to Infants, and described by *Tulpius* and others by the Name of Spina bifida ; in which, as in the Hydrocephalus, the bony Case is divided and vastly distended, as the stagnant Lymph is accumulated. *Ruyfch* has demonstrated Fibrills passing in a distinct and transverse Course from the cineritious to their Insertion in the external or medullary Substance of the spinal Marrow.

5 In every Process or Protuberance formed by the Brain before the Medulla oblongata, Nature seems to have studiously placed some of the cineritious Substance ; as we may plainly perceive in the Nates, Testes, Corpora Olivaria, and Pyramidalia, &c.

6 The medullary Substance of the Brain arises in distinct Portions from the cortical Part, and is afterwards divided or split into the several distinct Nerves of the Body : But any one of those Nerves being macerated in Water, divides or splits into a thousand Fibres or smaller Nerves, which were no less distinct from each other in the Substance of the Brain than in the Body of the Nerve. In short,

the nervous System may be well compared to a Tree, the Trunk of which is represented by the Medulla Oblongata, the Root by the medullary Substance of the Brain and Cerebellum, and the Branches by the several Nerves of the Body: But there is not any distinct Twig, or even Fibre, in the Branches of a Tree which were not also distinct from each other in the Trunk; nor any distinct from each other in the Trunk which were not equally so in the Root, as Dr. Grew has long ago demonstrated. We do not as yet enquire whether the medullary and nervous Fibres are pervious and tubular, but we here undertake to shew that the Medulla of the Brain is not a confused Mass like a Sponge, but an Assemblage of small Threads disposed in a distinct Order.

§. 271. The Course of these medullary Fibres is perceived to be as follows: (1.) Arising in distinct and very slender Fibrills from the spherical *Cortex*¹ investing the Medulla, they first converge towards the Center of a Sphere, and form the whole medullary Substance, from whence again diverging, the superior Fibres are collected into the *Corpus Callosum*² and Fornix, while the lower Fibres meet in the anterior and posterior *Crura*³ of the *Medulla Oblongata*⁴, and in the annular Protuberance; (2.) those of the Cerebellum, which arise like the former, *converge*⁵ and then unite with the two preceding, but they all combine in their three different Directions; (3.) all these Classes of medullary Fibres uniting into one Fasciculus or Bundle, compose
the

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the *spinal Medulla* ⁶; (4.) the like sort of medullary Fibres arising all round from the internal or cineritious Substance of the spinal Medulla, unite with every Point of the inner Surface of its white Medulla from the Encephalon, and give the last Increase to its Bulk.

¹ The Pia Mater forms many Arches, and gives the Cortex of the Brain a spherical Figure, that it might afford Rise to the greater Number of medullary Fibres.

² The medullary Fibres converging from all the upper Parts of the Cortex, unite together and form the Corpus Callosum, with its Fornix or arched Roof; after which they meet with a lower medullary Fibres and compose the third Ventricle: But the inferior Fibres of the Medulla terminate in the anterior and posterior Crura of the Medulla Oblongata, which combine with the medullary Fibres of the Cerebellum and the annular Protuberance; so that the Corpus Callosum and Medulla Oblongata may be reckoned the two Trunks or Foot-stalks to the Medulla of the Brain.

³ The Crura may be distinguished into two or four, according as the Lobes of the Brain are divided laterally, and into anterior and posterior.

⁴ This is composed (1.) of the converging Medulla, which is distributed into the nine Pair of Nerves: (2.) Of the Medulla from the Cerebellum, whence passing to the fourth Ventricle it ascends and unites with the Medulla Oblongata: (3.) Of the medullary Fibres from the upper Parts of the Brain, which passing over those of the nine Pair of Nerves, terminate in the spinal Medulla.

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⁵ Thus the Fibres of the Cerebellum all uniting with those of the Brain compose the Medulla Oblongata; and where the Medulla of the Cerebrum and Cerebellum meet together they form the annular Process or Protuberance; and the fourth Ventricle seems chiefly designed to keep the Crura of the Cerebellum distinct.

⁶ This Part is composed (1.) of the remaining Fibres from the Medulla Oblongata, after it has detach'd the nine Pair of Nerves; (2.) of those Fibres from the Cerebellum which did not ascend into the Medulla Oblongata; and lastly, (3.) of its own Fibres which come from its internal cineritious Substance and unite with the former.

§. 272. Since therefore the Fabric or Structure of these Parts is apparently such as we have here described, the Reason of the *Bulk*¹, *Figure*², and *Position*³ of the cortical Substance it thence obvious; and it is also thence evident that those Parts could not well perform their Office without the *Cavities*⁴ we call *Ventricles*⁵, the Necessity of which in the Brain is therefore apparent, since at the same Time that they prevent one Part of the Brain from injuring the other, they also give a free Liberty and Communication betwixt the whole Substance of the Medulla; from thence also appears the Reason of so many Protuberances observed in different Parts of the Medulla, as new Supplies of medullary Fibres arise from different Quarters and Directions.

¹ It was necessary for the cortical Substance to be more extended than the medullary, because but
a few

a few medullary Fibres arise from a large Portion of the Cortex; as is apparent in the medullary Peduncles of the Cerebellum, being no larger than ones Finger, when the Cortex of the Cerebellum, whence they arise, is full as large as ones Fist. Add to this, that every Point of the Cortex is an Assemblage of the several Series of Vessels disposed in Strata, from the sanguiferous down to the minutest invisible ones corresponding to but one single Point or Fibrill of the Medulla, which is therefore the Emissary of the ultimate Arteriolæ.

2 The human Brain was advantageously formed of a spherical Shape, because under a Surface of that Figure is contained the most Matter of any; and it was absolutely necessary for the Brain to be very large, as being the Foundation and Origin of all the other Parts of the Body, to which it is continued by the nervous Filaments; the Course and Distribution of which Nerves are more beautifully represented by *Eustachius* than *Lancisi* was able to explain them.

3 This appears from the Conveniency of the several Series of Vascules being expanded in Strata one within the other, which could not have been done in a plain Surface, nor in a membranous Expansion. And the cortical Substance was also placed withoutside of the Sphere, because there every concentric Circle is larger than towards the Center; so that by this Means, supposing the Cortex every where three Lines thick, it will be thrice as much as the Medulla, which Proportion is pretty near the Truth.

4 The Ventricles of the Brain are not empty Spaces in the living Animal, as they appear to us by opening and dilating them in anatomical Demonstrations; but whilst confined in the Cranium they are collapsed or close together, only they are

separated or fill'd with a moist Vapour or Dew : And the superior Concavities of the Ventricles closely adapt themselves to the lower Eminences of the same, so as to leave no intermediate Space. 'Tis true these have been thought by some to be empty Cavities, and there are many other supposed Cavities in the Body, which are void Spaces only in Imagination. The Cavity of the Thorax is entirely fill'd with the Lungs, the Stomach and Bladder contract to the Quantity of their Contents, and the Mouth can so close and approximate its Parts as to retain no Air or any Liquor, forcing its Contents back and down into the Gula for Deglutition.

^s *Galen* teazes himself wonderfully to give a Reason why the Hemispheres of the Brain are rather made hollow than solid and Compact. The Design of the two anterior Ventricles, which are the largest, seems to be for the more commodious Passage and Disposition of the medullary Fibres from the cortical Substance, as the former arise every way from the latter, converge towards a Center, and then go out of the Brain. For without this Contrivance one of the Inconveniencies following wou'd have ensued, *viz.* that either the Head and Brain must have been expanded flat like a Table, consisting only of two Strata, one medullary, and the other cortical ; or else the Medulla must have been placed withoutside the Cortex, which wou'd be inconsistent with the Design of the spherical Figure of the Brain N^o. 2. preceding. We also know that in solid Spheres, Fibres arising from the Circumference, and converging towards a Center, must perforate each other laterally in order to form Nerves, as we observed in speaking to the Medulla spinalis, §. 267. The third Ventricle of the Brain, a Fossa, placed betwixt the

two

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two posterior Crura of the Medulla oblongata, arises from mechanical Necessity, since the round Bodies of the Thalami of the optic Nerves cou'd not well touch, or come into Contact with the rest of the Brain without an intermediate Hiatus or Separation. The fourth Ventricle, which is a perpendicular Fossa betwixt the Conjunction of the Crura of the Cerebellum and Medulla oblongata, the upper Part of which Fossa is from its Shape termed *Calamus scriptorius*, does also arise from the same mechanical Necessity. The Ventricles of the Brain have also many Uses or Advantages in Life, such as the perpetual Exhalation of a thin Vapour, or moist Dew, to distinguish and separate the medullary Fibres from concreting or adhering to each other; and to convey those moist Vapours, when turned into Water, to the Infundibulum and pituitary Gland to be absorbed; as also to receive the reticular Expansion of sanguiferous Arteries, termed *Plexus choroideus*, which communicates Warmth to the cold Substance of the Brain.

§. 373. But it is highly probable that the medullary Fibres of the *Cerebellum*, which sends out no Nerves from its Medulla, ascend upwards from their Conjunction with the Medulla oblongata towards the anterior Part of the same Medulla of the Brain, where the several Pairs of Nerves are thence detach'd, and there joining with those Nerves, are thence continued with them to the several Parts of the Body; the Fibres from the Brain and Cerebellum being all the way very distinct from each other in their Origin, Progress or Distribution, and Offices; And this Commerce or
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Intercourse betwixt the Fibres of the Brain and Cerebellum will evidently appear to one who considers the various *Insertions* ² of the medullary Part of the Cerebellum into the Medulla oblongata of the Brain, and the *Increase* ³ of the latter thence arising; as also from considering the Return of the spinal Nerve from the bony Case of the Vertebræ into the Cranium, there to unite itself with the Nerve of the eighth Pair. But those other medullary Fibres of the Cerebellum, which are not thus detach'd with the Nerves, are so *intermix'd* ⁴ with the Fibres of the Brain, that there is not perhaps a single Point in the whole Medulla oblongata and spinalis, in which there are not as well Fibres of the Cerebellum as of the Cerebrum intermix'd; and therefore both are probably extended together in like manner in the Body of every Nerve for quite different and distinct Offices or Effects.

¹ The Brain or Cerebrum seems to be the Seat of animal Action in the human Body, and the Cerebellum the Seat of the vital Actions or Functions (*per* §. 600.); but the Faculties of Sensation and voluntary local Motion cannot subsist separately without the vital and involuntary Actions: And this may probably arise, because the Fibres of the Brain are in no Nerves extended without the Fibres of the Cerebellum, nor can we affirm that any one Nerve comes only either from the Brain or Cerebellum.

² All the Medulla of the Cerebellum is not spent in the spinal Medulla; for a considerable Part of the former ascends forwards, and conjoins itself with

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with the Fibres of the Cerebrum, as *Vieuſſens* and *Ridley* have obſerved ; and this that they might be extended with the Fibres of the Nerves which ariſe from the Brain ; ſo that the Nerves of the Medulla oblongata have their Origin in part from the Cerebellum as well as from the Brain.

³ It will readily appear to a conſiderate Enquirer, that ſo large a Body as the Medulla oblongata cou'd not ariſe from the medullary Fibres of the Brain only, without the Conjunction of the Fibres from the Cerebellum ; even the whole annular Pro-tuberance is compoſed of the medullary Fibres from the Brain and Cerebellum intermixed.

⁴ So that no one Nerve ariſes from the Medulla oblongata but what has Fibres both from the Brain and Cerebellum ; nor is there any Point of the Medulla oblongata, nor of the ſpinal Medulla, in which there are not the Fibres of both interſperſed ; if we except only the olfactory Nerves, which ſeem to ariſe from the Brain only : But it does not follow that theſe two Sorts of medullary Fibres are confounded indifcriminately together becauſe they are intermixed ; for tho' in their Diſtribution they are frequently interwoven and confounded in Plexus's and Expansions like as the Cauda equina ſplits into an infinite Number of nervous Threads, like Hairs, without obſerving any regular Order in their Courſe, yet every Thread is very diſtinct from each other, and regularly diſpoſed from their Origin at the cortical Subſtance to their Expanſion in nervous Filaments.

*Concerning the Juice or Spirit of the
Brain and Nerves.*

§. 274. **W**Hoever then, with regard to the secretory Office of this Part, *considers* ¹ (1.) the foremention'd Nature or Fabric of the Cortex (§. 263 to 266.), with that of the distinct *medullary* ² Fibres thence arising (§. 270.) ; (2.) the Similitude of this secretory Apparatus with that of all the other Glands in the Body ; (3.) the vast Quantity of very thin, pure and fluid arterial *Blood* ³, so strongly propell'd hither by the adjacent Heart, before it has lost any of its more subtile Juices ; (4.) the *very thin* ⁴ lymphatic Juice, which always appears within the medullary Substance of the Brain in Dissections, manifest not only to the Touch and Taste, but also to the Eye, especially when armed with a Microscope ; and which Juice is often found in a much increased Quantity in most diseased Brains ; (5.) that the *Veins* ⁵ of the Pia Mater return the Blood from the cortical Substance of the Cerebrum and Cerebellum into the Sinus's of the Dura Mater, to be thence convey'd by the jugular Veins and Cava to the Heart ; (6.) the constant, regular and proportionable Growth or *Increase* ⁶ and Nutrition of the Stamina or small Threads of this Part, which are continually destroyed

destroyed and repaired from the first Beginning even to the Period of Life : Whoever considers these, must judge that the medullary Fibres are small pervious Tubuli, receiving the most *subtile* ⁷ Juice of any in the whole Body ; which being prepared and separated in the wonderful Fabric of the Cortex, is thence propell'd from every Point thro' these Tubuli into the Medulla oblongata, and there collected.

¹ 'Tis true, we now assume an Argument which cannot be demonstrated to our Senses, since the most exquisite Researcher into minute Objects, *Lewenhoec* himself, confesses that his Glasses could never make out to him the most minute Fabric of the Medulla ; we must therefore have Recourse in this Case to the Method we are often obliged to use in physical Matters, that is, by Reason and Analogy to trace the Structure or Fabric as a Cause *à posteriori*, or from the obvious Phænomena and Effects ; from these we are therefore to judge, whether the medullary Fibres (§. 270.) are either solid and impervious, or tubular, and so formed from a Number of small Vascules, as to receive and convey a Liquor thro' their Cavity.

² We have before shew'd (§. 265.) that the first vascular Stratum of the Cortex, which is next to the Pia Mater, consists of red or sanguinous Vessels, from whence arise the other Strata or Vessels in the Cortex, which admit such Juices only as are pellucid and thinner than the red Parts of the Blood itself ; and we know that such pellucid Vessels as are separately invisible appear together of an ash or grey Colour, like Flint Glass. We also know, that where the most subtile Part of this cortical Substance terminates, there the medullary

Part

Part apparently begins : But we have not any one Instance throughout the whole human Body of Vessels terminating in a solid or blind Extremity (§. 132. N^o 20.) ; but open either into other Vessels or into some Space or Cavity ; otherwise the Circulation of our animal Juices would cease : 'Tis therefore hence probable, that as the smaller pellucid Vessels arise from the sanguiferous or red Vascules of the Cortex ; so from the smallest Series of pellucid Vascules in the Cortex arise the very minute Tubuli of the Medulla. How preposterous and unparallel'd wou'd it be to assert, that the Blood and its most subtile Juices are convey'd to solid and impervious Fibres in the Medulla, and then returned again by the Veins without performing any thing but its Circuit ; this wou'd be not only repugnant to the wise Oeconomy of Nature, but also refuted by the Instance of all the other Viscera, especially the Kidneys, where the secretory Tubuli arising from the cortical Fabric bears some Analogy to this Part ; and if it be said that in the Spleen the Blood passes without performing any thing there besides its Circuit, we answer, that there we have no Appearance of any secretory Tubuli, but only a Congeries of Vessels.

3 *Malpighi* shows how vast a Quantity of Blood is impell'd to the Brain (§. 239.), which at least receives more than any other Viscus ; nor is the Brain ever deprived of its great Quantity of Blood, even in tabid or consumptive Patients whos Bones are visible thro' their Skin ; for in such we observe the Cranium quite full, and the Brain as large and as sound as ever. I can hardly believe any one will entertain a Notion so absurd, as to think that all this vast Quantity of Blood is sent to the Brain for nothing, as it must be if there is no Secretion there made from it ; for if the Blood was only sent
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by the Arteries to the Brain, and again return'd as it went by the Veins, all this vast Quantity of Blood, amounting to near one third of the whole Mass, would be in a manner lost, and take this Course for no Use either to itself or the Brain.

⁴ I have frequently observed that by dividing the Medulla oblongata with a very sharp Razor, and then inspecting with a Microscope, there appears little Drops of Moisture transuding like Dew, which presently exhale and dry up, or if you wipe or scrape them off, they are presently again renew'd. If a Brain be distill'd with a very slow Fire, or a Heat not exceeding that of boiling Water, it quickly turns almost wholly into a lymphid Water, leaving very few solid Vessels behind. The Liquor found in the Ventricles of the Brain in a healthy Man that has died a violent Death, wholly evaporates with Heat, as *Bellini* observes; and the Substance of the Brain itself, freed from the Pia Mater, almost wholly evaporates in the Shade; but it is not probable that the Vessels themselves evaporate; only the small Vessels having exhaled their Liquors collapse and shrink up to a Membrane. This Liquor of the Ventricles is also frequently observed in great Plenty after lethargic Disorders of the Brain, which has been taken Notice of even by the Ancients, who therefore pronounced a moist Brain to be attended with dull Intellectuals.

³ Where-ever the Blood is driven into a Part by Arteries; and returned again by Veins, there is always some Secretion made from it; nor is there any Reason to be offer'd, why such a Secretion shou'd not be performed in the Brain.

⁶ This is an Argument next to a Demonstration: For in the human Animalcule, less than a Grain of Sand, and in the incipient Foetus, no bigger than

an Ant, there is both a Brain, Cerebellum, and spinal Marrow; all which grow and increase in Proportion with the rest of the Body: Supposing then that the Brain and its Appendages are augmented and nourished like the rest of the Body, that is, by an uniform and equable Distention of Parts, by the Juices propell'd thro' the Arteries by the Force of the Heart; the same Causes must be then admitted in the Brain, *viz.* a Supply of Juices from the Heart to every individual and minutest Fibre, of the Medulla as well as the Cortex; or else how does the first grow and increase if it be only solid Fibres, having no Commerce with the Arteriolæ of the Carotids. I therefore conclude for my own Part, that this Argument is little inferior to an ocular Demonstration; nor can any Objection of Consequence be raised against it; even the Minuteness of the Vascules rendering them invisible is of no Force against us.

7 The great Tenuity of this Juice is apparent from the Experiments of *Ruyseh*, by which he cou'd never inject the smaller Arteries from whence it is separated; for when I have been present with this celebrated Anatomist about to inject, he has declared to me before-hand, that he cou'd not promise his Injection wou'd succeed equally alike, but sometimes one Part happen'd to take well, and sometimes another: And in the fullest Injection he ever made of the Brain, the Arteries of the whole Pia Mater were distended, and some small Part of the Cortex next the Pia Mater look'd red; whence the smaller Vessels next continuous to the red injected ones were dissolved when he compleated his Preparation by macerating in Water, in order to suspend it in Spirit of Wine. And it is evident that many of the Vessels in the Cortex were fill'd by his Injection with a much greater Force than is ever exerted

exerted naturally, since no Part of the Cortex ever appears red without Injection; and therefore the smallest of the injected Vessels in his Preparation were naturally pellucid or serous, and not sanguiferous Arteries: In the same manner too we observe but very few sanguiferous Arteriolæ creeping on the Albuginea of the Eye, when it is not inflamed; but in Ophthalmias and the Preparations of that Tunic by *Ruyfch*, it appears all over red, by Blood or Injection being forced from the sanguiferous into the first, and perhaps the second Series of lymphatic Arteriolæ thence arising; but the greatest Part of the Cortex, which is only many Strata of Vascules, we see cannot be injected; and therefore it follows that the Cortex must contain many more Series of lymphatic Arteriolæ still smaller than the first and second Order, which cannot be enter'd or injected by the most subtile coloured Liquor.

§. 275. And if, with regard to the Nature of this Juice, we again consider (1.) the particular State or Disposition of the Blood brought to the Brain by the carotid and vertebral Arteries (*per* §. 224 and 235.), by which it differs from all the other Blood in the whole Mass; (2.) the most subtile or minute Structure of the evanescent Arteriolæ, coming from the Vertebrales and Carotids, vanishing in a sort of downey or cotton-like Pulp, and by an inscrutable Implication and Contexture forming the Substance of the Cortex (§. 236.); (3.) the particular Nature of that Juice (§. 274. N°. 4.) which so suddenly exhales of its own Accord, and does not harden with Heat as do the lymphatic

phatic Juices, and which so nearly evaporates as to leave little or no Residuum ; (4.) the great Power and *Celerity*¹ with which we daily observe this Fluid act in the Nerves and Muscles ; Whoever considers these and the preceding Circumstances (§. 274.) will readily conclude the component Particles of this Juice are the most simple, *dense or firm*², subtile and *moveable*³ of any Juice throughout the whole Body.

¹ I no sooner will the Extension of my Arm, but the Action instantly follows without any sensible Interval : But this Action of the Mind must be first exerted in the Brain, notwithstanding M. *Per-raull*'s Opinion to the contrary. We are furnished with innumerable Experiments which argue against him, and demonstrate that the Brain being obstructed or destroyed, the voluntary Motions are thence suppressed ; and that by intercepting the Commerce betwixt the Brain and any Part, that Part immediately ceases to be governed and actuated by the Mind. But if the muscular Motion of a Part so immediately follows the determinate Action in the Brain, it is evident that no Juice can suffice for the Office, but what is apt to move the swiftest and easiest of any.

² Tho' the nervous Juice or Spirits separated in the Brain are the most subtile and moveable of any Humour throughout the whole Body, yet are they formed like the rest from the same thicker Fluid the Blood, passing thro' many Degrees of Attenuation, till its Parts become small enough to pervade the last Series of Vessels in the Cortex, and then it becomes the subtile Fluid of the Brain and Nerves. But as far as we can perceive, all the circulating
Juices

Juices in the Body consist of spherical Particles, and therefore this circulating Juice of the Nerves probably consists of such figured Particles, only simple, or the least compounded of other smaller Spherules of any Humour in the whole Body ; and therefore such simple or least compounded Spherules will be the most solid, or the least apt to divide and break into less. They will be more dense, solid and permanent, as being simple Spherules ; whereas the other larger Spherules, compounded of several smaller, intercept Pores, and are thence lighter, more divisible and unactive. Thus Gold, whose elementary and constituent Particles are altogether similar and very compact, is a most durable or permanent Body, not capable of being destroyed even by the intensest Fire.

³ They will be the most fluid or moveable of any Particles, as having no Tenacity or Viscid Cohesion to each other, by which they will very often change their Contacts by the least Force ; otherwise they wou'd never exhale so readily (*per* §. 264.)

§. 276. But the red Parts of the Blood appear by the Microscope to be the grossest or *largest* ¹ of all that are contained in any of our healthy Juices ; and in the mean time the Serum, consisting of Particles much smaller than the red Cruor, is subdivisible into Corpuscles or Spherules incredibly less than any we can observe in it, as may appear from the Increase of the Fœtus or *Carina in Ovo* during Incubation, where the Albumen, which is thicker than the Serum, is successively so attenuated, that it at length becomes capable of pervading all the inconceivably small Vessels in the little

Embryo: Even the least Insect in the World has its infinitely numerous and different Vessels, pervaded by their respective Juices, not excepting those infinitely small Animalcules discernible with good Glasses in the Semen masculinum; from all which it is evident that the Particles of this very subtile Juice, or Spirit of the Brain and Nerves, are to be esteemed vastly smaller than they are generally imagined to be.

Trusting to Reason and Experiment to conduct us in our present dark Enquiry, I shall endeavour to show you by a familiar Instance, how a gross Liquor may afford a very subtile one barely by Heat and Attrition. We know by *Leuwenhoeck's* Observations (§. 226.) that each red Globule is compounded of six smaller serous ones, into which they dissolve or separate by a gentle Heat; Now this same Serum into which the Cruor is resolvable, does by the Heat of scalding Water concrete like the White of a boiled Egg; but being digested with a very gentle Heat, only equal to that of a healthy human Body, it dissolves or turns to a very thin and pellucid Serum almost like Water. In the Egg which weighs about two Ounces, under a sitting Hen, various Juices are contained within the Shell, the Calaza or white Ligaments, Albumen, Yolk, and Cicatricula; which last is a little whitish Sacculus, about the Size of a small white Pepper-corn, and full of a very lympid Liquor, in the midst of which is lodged a white Spec no bigger than the Head of a minikin Pin, and of a very high Relish or Taste. The Egg fill'd with these several Juices, and placed under the sitting Hen, is found to have diminish-

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ed in its Albumen upon opening it on the third Day after Incubation ; while the Cicatricula or little Sacculus of Colliquamentum is at the same time proportionably larger, and the Spec or Point in it has a visible Pulsation, and is enlarged into the Form of a Vermicle: Also if you break an Egg at long Intervals after Incubation, the Albumen will always be found proportionable less or more diminished as it has been longer sit upon, and the Carina or incipient Chick with the Amnios or including Membrane appears so much the more enlarged. Lastly, if you break an Egg on the twentieth Day after Incubation, there will be found little or none of the Albumen in the including Shell and Membranes ; while the Yolk at the same time appears to have undergone little or no Alteration, but the Sacculus or Amnios is surprisngly distended, and contains the Carina or Chick so much augmented, that itself weighs near the whole two Ounces of the Egg. Hence it manifestly appears, that the Albumen only is the Matter from whence the whole Body of the Chick is formed in the Space of twenty-one Days : But this Albumen is a gelatinous Liquor included in concentric fine Membranes or Lamellæ, continually lessening and refining in Texture towards the Center, like Coats of an Onion, the Yolk itself and the Colliquamentum or Carina being the Center of those Lamellæ. These Liquors of the Egg quickly putrefy if it be not prolific, and becoming volatilized exhale thro' the Pores of the Shell and including Membranes ; nor will they then harden with Heat like as in a sound Egg, which affords a certain distinguishing Sign to detect an addled or unsound Egg. But if the Egg was fecundated by the Cock, and then retained in a gentle Heat, then the thick Albumen is successively attenuated from one Lamellæ to ano-

ther, and being elaborated in the small Glands of the Yolk is at length convey'd by the omphalomesenteric Vessels of *du Verney* into the Intestines and Veins of the incipient Chick; and is lastly converted into its several vital Juices, pervading even the Brain and Nerves in Form of such a fine Liquor as will not harden, but easily exhale in Vapours. In the same manner the Serum of the Blood (which is so much of the same Nature with the Albumen, having the like Tenacity, and hardening with Heat) is gradually so attenuated by the perpetual Attrition given to it by the Arteries, that by passing thro' various Degrees of Tenuity, it at length loses its Tenacity, and becomes a most subtile, moveable, and volatile Liquor, pervading thro' the cortical Part of the Brain, which admits none of the red Blood (*per* §. 235.): And it is not improbable but that the several Strata of decreasing Vessels in the Cortex may be concentric, and analogous to the several Lamellæ of the Albumen in the Egg.

§. 277. From what has been said we may also affirm that this Juice is of a very different Nature from any *saline* ¹ Substance whatever, whether produced by Art or Nature; because we observe that all the Properties or Affections of the said Juice are vastly foreign to all those of saline Substances: And much less can it be formed of any *oily* ² Matter hitherto known; since such Substances are injurious to the Tubuli or hollow Fibres contained in this Juice. Nor has it any Resemblance to the *Spirits* ³ produced from vegetable Matters by Fermentation; because those Spirits, in their purest State,

State, first shrink and dry up the Fibres or Tubuli, and then render them unfit to perform their Offices. 'Tis rather more probable, that this Juice or Spirit of the Brain and Nerves is like those of the most subtile and pure Water, from their agreeing so nearly in the Solidity, Smoothness, Simplicity and great Fluidity, or Disposition for moving, and their want of Elasticity; notwithstanding we are assured that they arise from other Materials than Water, as appears from the Transmutation of the Juices in an *Egg* ⁴ by Incubation.

* Whether acid or alkaline; notwithstanding the Chemists teach that the Spirit or Juice of the Brain is composed of volatile Salts much more penetrating than Water; because, say they, such Salts arise from the Blood and Juices when exposed to a Heat the same with that of a healthy Body which comes near to the Heat of a sitting Hen; *M. Paschal*, and others, again suppose them acid, and Dr. *Mayow* thinks them like to the aerial Nitre; but 'tis notoriously obvious to every one, that the Substance of the Brain has naturally no Taste or other Property belonging to Salts; on the contrary, there is not any one Part in the whole Animal more insipid, insomuch that it is scarce eatable without a great deal of acid, Sea-salt, or other Sauces; or were the Tubuli of the Brain and small Vascules of the Cortex to be pervaded in their natural State, by such acrid saline Juices they would be totally dissolved together with the Medulla of the Brain and the Substance of the Nerves themselves; nor could saline Particles pass through such minute Tubuli, which are too small to admit even the Parts of Water itself,

² *Willis* supposes the Medulla of the Brain to be of an oily or sulphurious Nature, a Property the remotest of any from the Nature of this Juice, which if it were like Oil would be too tenacious to enter such minute Passages and move so swiftly as we often observe in the Muscles, &c. *F. Redi* observed that Serpents and Fish included in a close Vessel turned into a fætid Liquor, like a pellucid Water, with some Oil swimming on the Top, from the Fat of the cellular Membrane under the Skin, &c. which shews that animal Juices are not of a sulphurious Nature.

³ This Hypothesis, which we are going to refute, has pleased many celebrated Physicians, and some who have professed in the present Chair of *Leyden*; where it has been taught that a Catalepsy is Congelation of the animal Spirits by a volatile alkaline Salt, in the same manner as Alcohol Vini and Spirit of Sal Ammoniacum do upon Mixture run into the solid *Offa Helmontiana*. There are indeed many ways of refuting this Opinion: For neither is there any Fermentation in the human Body whereby to generate a vinous Spirit from an acid or vegetable Juice, nor is there any Fire and Apparatus in the same to distil and separate such a volatile, oily, and inflammable Spirit; nor could it, if it was separated, pervade the small Tubuli of the Brain and Nerves, since it in a great measure partakes of the Tenacity of Oil, as appears from its running down the Sides of a Glass in Striæ; and since by its strong Attraction of Water or constringing Quality, whereby it preserves anatomical Preparations, it wou'd indurate and close all the Vessels and Passages. Nor does the Juice of the Brain manifest any phlogistic Quality, but extinguishes a Flame when thrown upon it; nor can it resist being

ing frozen by the most intense Frost, as Alcohol will.

4 The Matter from whence the Juices or Spirits of the Brain are prepared, is the Viscid and tenacious Serum of the Blood, which by passing thro' many Degrees of Attenuation, at length acquires the Subtility of a Spirit, after its Particles have been moulded or formed by passing frequently thro' the smallest Series of Vessels in the Body; passing from Blood into Serum, from Serum into Lymph, and from Lymph of the first Order in all successive smaller ones, till at last losing the Nature of Lymph it acquires the subtile one of a Spirit. But as the Albumen of the Egg is so much like the Serum of the Blood, and the Heat of the human Body so near to that of a sitting Hen; we shall, perhaps, not judge amiss if by Analogy we reckon the Time required to prepare one Juice by the other; *i. e.* as the Albumen takes twenty-one Days time to turn it rotten or else digest it into the healthy Juices of the Chick, so the Serum of the Blood may take about the same time to digest and break it small enough for this Juice of the Brain; for similar Causes generally yield similar Effects. This Juice is therefore not a mere Water, for that wou'd be too rigid, and its Parts would have none of that mild Tenacity necessary for their adhering to the healthy Fibres for Nutrition; nor is Water a Cordial, but those Liquors only are Cordials, which are either themselves apt to turn into good Blood, or which so augment the Powers of Life, as to convert the Blood into nervous Fluid by making it pass through all the several Degrees of Attenuation. Too plentiful drinking of watery Liquors and Water only are so far from recruiting the Spirits, that, after a short Flow of Spirits, they infringe and weaken all the vital Powers. A Redundancy

dundancy of Water is the frequent Cause and Companion of Lethargies ; and yet, notwithstanding, the Nature of the nervous Juice is not very remote from that of Water ; for if the whole Brain be distill'd with a Heat equal to that of boiling Water, it affords the greatest Plenty of that Liquor, differing little or nothing from simple or pure Water ; though by a stronger Heat you may also obtain the same Salts, Oils, &c. as from the Blood (*per* §. 227. N^o 2.)

§. 278. We are again convinced that the Quantity of this Juice must be very *large*¹, and be perpetually renew'd or made afresh every Moment while we are alive and well ; as may appear from considering the Magnitude or Size of the carotid and vertebral Arteries ; from their direct and ready Course to the Head, free of all Impediments ; from the vast Quantity of Blood impell'd through them by the Heart ; from the greater Velocity with which it arrives, and from the vast Quantity or Extent of the cortical Substance, all which sufficiently prove the Largeness of the Secretion.

¹ If we examine the Brain and its Appendages, to wit, the Cerebellum, Medulla Oblongata, and Spinalis, we shall find no other Viscus so large in the whole Body ; and if to that Consideration we add the great Quantity, Velocity, and direct Course of the Blood sent thither by the very adjacent Heart, and that this Blood is more refined and replenished with spirituous or easily moving small Particles than any other Blood of the whole
Mass,

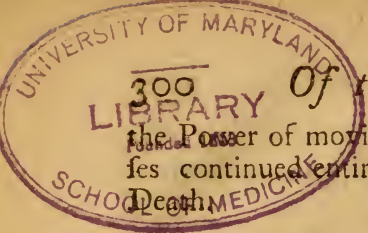
Mafs, we may then readily conclude that this Juice is prepared very copioufly and powerfully.

§ 279. And ſince the Office of this tender Apparatus is ſo important, therefore the whole Encephalon is included and defended in a Caſe of reſiſting *Bones* ¹, without being loaded or preſſed by any incumbent *Fat* ², Muſcles or other Bodies ; and as its Arteries and Sinus's are alſo equally ſecured from ſuch Incumbrances in their Courſe, keeping always the ſame State or Diameter, it follows from the whole, that this Juice will be *equally* ³ and uniformly prepared in the ſaid Viſcus.

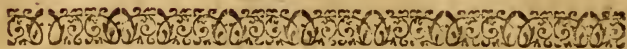
¹ No leſs ſurpriſingly than advantageouſly framed of eight diſtinct Bones, of different Figures, ſo connected as to give way and yield to the Extension and Growth of the Inhabitant, which is thus ſecured from Injuries and Compreſſure.

² There are indeed ſome few Inſtances of Fat being obſerved about the Brain, but never without fatal Conſequences, as you may ſee in *Bonneti Sepulchret. Anat.*

³ We have before obſerved, that the Brain is not liable to that Stimulus or Preſſure of the Muſcles, which increaſes many Secretions more at one time than at another ; nor does it waſte or fail of its juſt ſupplies from the Heart, even in the laſt Extremity of a Conſumption, where a little before Death the Patient's Senſes are in great Perfection ; and after, the Cranium appears full, and the Brain perfectly entire : And thus I remember a little Girl who was ſo waſted in an Atrophy, that all the Blood-veſſels quite vaniſhed, and ſhe had not
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the Power of moving any Limb, and yet her Senses continued entire even to the very Article of Death.



Of the Nerves.

§. 280. **I**N the next Place the Medulla oblongata¹ and spinalis, (invested with a very thin Membrane composed of exceeding minute Vessels, discover'd by the *Ruyschian* Art of injecting, and consisting of the medullary Fibres of the Brain and Cerebellum collected together) sent forth within the Skull, in twenty different places, *ten*², falsely call'd, Pair of Nerves, since most of them consist in reality of several distinct and large Nerves joined together; but from the spinal Medulla without the Cranium arise in the same manner *thirty*³ Pair of Nerves, which are, like the former, very much compounded of other lesser ones; besides one Pair of Nerves arising out of the Cavity of the Spine or Vertebræ of the Neck, near the fourth Pair of vertebral Nerves; and uniting in its Ascent with Branches from the second and third Pair, it thereby becomes gradually thicker and larger, till it at last joins with the eighth Pair of Nerves.

¹ The cortical Part of the Brain receives the most subtile and pellucid, rejecting the red Parts of the Blood from the Pia Mater; which more subtile Parts

Parts of the Blood pass successively thro' the several smaller Series of Vessels in the Cortex, till being highly attenuated, it at length enters the medullary Tubuli: But the Fibres of the Medulla are all collected into that of the Oblongata, and then sends forth Nerves, which never arise separately either from the Medulla or Cortex of the Brain alone, but from the Medulla oblongata and spinalis, formed by the Conjunction of the Medulla of the Brain and Cerebellum together.

² Rather nine Pair, the last of which belong to the Tongue; for the tenth is an accessory Pair, arising from the Medulla spinalis, and entering within the Cranium, it joins with the eighth Pair of the Brain, and then returns out of the Cranium again.

³ The spinal Nerves strike off nearer from their Origin or Medulla in the Case of Vertebræ, than those which come from the Medulla oblongata within the Cranium. The last Extremity or Termination of the Brain is near the Os sacrum, in a numerous Assemblage or Bunch of nervous Filaments, termed from its Appearance, the *Cauda equina*.

§. 281. All these Nerves, while concealed within their medullary Substance, are of a soft and pulpy Consistence; but passing out from the Medulla they are cover'd with an *Integument*¹ from the Pia Mater, wherein they are secured as they proceed, and then perforate the *Dura Mater*², which is extended round them in canular Productions like a Sheath, reaching as far as the Foramina of the Cranium thro' which the Nerves pass, where
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the Integument of the Dura Mater unites with that of the Pia Mater; and closely investing the nine Pair of Nerves with the accessory Pair, secures them wonderfully in their Progress from the Cranium: but the other thirty-one Pair of spinal Nerves descend downwards thro' the broad and artful Spaces formed betwixt the Margins of each vertebral Apophysis; from whence emerging, they are immediately after secured by their Integuments, and becoming firm and compact are dispersed thro' every individual Point of all the several solid Parts of the Body with which we are yet acquainted.

¹ The Consistence of the Nerves, as they arise in the Brain, is very soft and medullary; but having reached the Margin of the Medulla oblongata from whence they emerge, they first receive an Integument or Coat there from the Pia Mater, as is generally said by Anatomists; but the optic Nerve has its medullary Substance apparently invested with an Integument much harder than can be well derived from that Membrane; nor does the said Tunic perform the Office of the Pia Mater, since none of the Nerves are furnished by the cortical Substance or Fabric. Upon this last Tunic, immediately investing the medullary Substance of the Nerve, is spread the Tunica Arachnoides, and cellular Membrane, thro' which the small Vessels are distributed on the Surface of all the Nerves.

² The Dura Mater not only invests the whole Surface of the Cranium internally, but is also extended without, over all the Nerves which pass from the Cranium, and accompanies them even in their Distributions. I examined the spinal Medulla after
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it had been with much Labour freed from its Case of Bones, from the Occiput to the Cocyx, by an indefatigable Anatomist, and cou'd then see many Fibres of the Medulla descend and run together into a Bundle forming one Nerve, which passed out thro' a Foramen of the Dura Mater, which gives a very strong and hard Coat to the Nerves, which after they are gone some way from the Spine, join together in Ganglia, or Knots of a hard, fleshy, or cartilaginous Texture; but the medullary Part of the Nerve continues of as soft and mucous a Substance in the smallest Fibrils, as at its Origin in the Brain itself. Thus the optic Nerve taken together seems tough and hard, but on dividing it transversely, the mucous medullary Substance is forced out from its containing Integuments by their natural Contraction; but there is no Necessity for you to divide or wound the Nerve to be convinced of its Medulla; for by tracing it a little farther from the Cranium, it puts off the hard Integument received from the Dura Mater, and therewith forms the Sclerotica or hard Coat confining the whole Globe of the Eye; it then also deposits the inner Coat, received from the Pia Mater and Tunica Arachnoidea, which forms the Choroides of the Eye next to the Sclerotica; so that these Membranes being deposited from the Nerve, it is now expanded in a soft medullary Plexus termed the Retina. The same is also true of the auditory Nerve, which deposits the two Integuments it received from the Dura Mater, within the auditory Sinus; and that from the Pia Mater is thrown off upon the Tympanum, while itself continues expanded in the Cochlea and semicircular Canals a mere Mucus or Medulla: Whence it is manifest, that the callous Hardness of the Nerves arises from their including Membranes, in which the Medulla

from

from the Brain retains its original Disposition without any Change throughout their whole Distribution to every Point of the Body. So that which is shew'd in anatomical Demonstrations under the Name of a Nerve, is a small Portion of the medullary Substance included in tough Membranes.

§. 282. But these Coats of the Nerves (§. 281.), are every where spread with small *sanguiferous* ¹, lymphatic, and other Vessels, investing their whole Fabric very closely; so that they do not constitute this Part as a Nerve, but only serve to collect, secure and convey the medullary Fibrills or Tubuli to their respective Parts; from considering which, you may account for many Phænomena and Diseases of the Nerves.

¹ My Friend *Ruyfch* writes in an Epistle to me, that his Injection succeeds the most beautifully when forced in by the umbilical Vessels of a Calf that has been lately dropp'd: For then even the Integuments of the Nerves appear beautifully painted with Blood-vessels. In the optic Nerve we observe four little Arteries running externally in its hard Integument, without entering its medullary Substance, since they belong only to the Membranes: But the Medulla of the Nerve has an Artery running thro' its Axis or Center, and expanding itself laterally with the Retina, and causes a blind or insensible Point in the Center of the Retina. There are an infinite Number of sanguiferous Vessels distributed in the Dura Mater and its Membranes, and there are doubtless Lymphatics also of the several smaller Series: All which Vessels, even those of the Brain and Nerves, are invested with the cellular Membrane;

Membrane; and therefore here seems to be the Seat of many nervous Disorders which are independent of the Brain, such as one Species of the Rheumatism and Gout, tho' the former is generally seated in the vascular Plexus's of the Membranes, Tendons and Muscles; and the Species of the Gout which I mean, is that termed by *Hippocrates* the profound Separation of the Blood, &c. which Disorders, as also Palsies of the Joints, where the Brain is unaffected, may be removed by topical Remedies, as I have myself experienced; which can hardly be expected, when the Seat of the Disorder is in the Medulla or Brain, such as Palsies following Apoplexies, Lethargies, &c. which are never curable without restoring the Brain to its former Integrity.

§ 283. But when the ultimate Fibres of these Nerves enter the Parts to which they are determined, they then deposit the *Coats* they before received from the Meninges, and are soon after expanded in Form of a very thin and tender Membrane, or else end in a soft Pulp.

* We have already observed this of the optic and auditory Nerves (§. 281. N^o. 2.); and it is the same with the olfactory Nerves, which approaching the *Os cribrosum* pass thro' the little Sheaths or tubular Productions of the Dura Mater, and then expand like a soft Pulp on the Membranes of the Nose, giving way to the least Pressure like a Mucus. The small tactile Nerves are demonstrated by *Malpighi* and *Ruysch* to be very strong and hard till they reach the reticular Body of the first, under the Cuticle, where they deposit their Integuments

ments of the Dura and Pia Mater, the last forming the Corpus reticulare *Malpighii*, and the former the Cuticle, while the pulpy Substance of the Nerves themselves is formed into little Heaps termed Papillæ; and if you remove the said Cuticle and reticular Body, there appears underneath them a Congeries of naked, soft, gelatinous and very sensible Papillæ in the true Skin. If powder'd Cantharides are applied to any Part of the Skin, and suffer'd to remain too long on the Part, as I have sometimes known, and then a strong Basilicon-Plaister imposed over the naked Papillæ, after the Cuticle has been elevated and the Papillæ much corroded by the Acrimony of the Flies, it excites such an excruciating Pain in the said Papillæ, which are then easily discernible by the Microscope, that Convulsions and even Death itself have been known to follow. And the same direful Symptoms will also follow upon an ignorant Surgeon's scraping off the said nervous Mucus or Papillæ appearing under the dead or destroyed Cuticle. All the Nerves therefore in the Body terminate one and the same way, nor is the least Fibre or solid Part of the Body without its Nerve, or which is not as well supplied with the nervous as with the arterious System.

§. 284. If we therefore attentively *consider* ¹, (1.) that the medullary Substance (§. 270, 274.) wholly pervious or tubular, is entirely spent in composing the small Fibres of the Nerves, passing into them alone in one continued Course without any Interruption; (2.) that if the Medulla of the Cerebrum or Cerebellum be *compressed* ², wounded, putrefied or eroded, all the Actions of the Nerves thence arising are immediately abolished or destroyed, notwithstanding

standing the Nerves themselves and their Integuments are entire and without Injury; (3.) that all the Nerves very readily perform their Office, tho' they are every-where either lax or pendulous, and disposed either in oblique, *crook-ed*, and inflected or retrograde Courses; (4) that the Nerves being compressed or tied, even without wounding 'em, the Parts to which they belong, betwixt the Ligature and *Extremity*¹, lose all their Faculties of Sense and Motion, while those Parts which are supplied by the same Nerve betwixt the Ligature and Medulla of the Brain are unaffected; whoever reflects on these Circumstances will readily conclude, that those Fibres or Tubuli of the Nerves continually *receive* the Juice of the Medulla (§ 275 to 278.), and transmit the same by very distinct Passages to every individual Point of the whole Body, and that by the Conveyance of this Juice only they perform all their Actions and Uses as Nerves.

¹ There are two Opinions which at present prevail with regard to the Nerves, some thinking them pervious and filled with a kind of Juice subservient to Sensation and muscular Motion, which is one Opinion; others suppose them stretch'd from their Origin like tense and solid Chords, conveying the Impressions of Objects to the Sensorium, and performing the Motion of the Muscles by mere Vibrations.

² There was a Man at *Paris* who at times begg'd Money in a Piece of his own Skull, his Brain being only cover'd with the Dura Mater; and he would frequently permit Experiments to be made

for a small trifle of Money. Upon gently pressing the Dura Mater with one's Finger, he suddenly perceiv'd, as it were, a thousand Sparks before his Eyes; and upon pressing a little more forcibly, his Eyes lost all their Sight; by pressing the Hand still stronger on the Dura Mater, he fell down in a deep Sleep, which was attended with all the Symptoms of a slight Apoplexy, merely by this Pressure with the Hand; which was no sooner remov'd, but he as gradually recover'd from the Symptoms as they were brought on, the apoplectic Symptoms first vanishing, then the Lethargy, and lastly the Blindness, all his Senses recovering their former Perfection. This is a manifest Argument, that the Source of Motion and Sensation is in or dependent on the Brain, which being free and unaffected they are also in the like manner duly exercised, but by any Discomposure of the Brain they are proportionably impaired or abolished. If a small Artery is ruptur'd within the Cranium of the most healthy Person, by the Efflux of an Ounce or two of Blood from thence, the internal Parts of the Brain and Medulla will be compressed, and the Patient will perceive, first, a kind of red Atmosphere or Vapours about his Eyes; after which every thing will seem to turn round, and he will at last fall down apoplectic, destitute of all the animal Faculties, and without Sensation or any voluntary Motions; but as in this Case there is no other Change made in the Brain and Nerves but a Compressure of their Origin, it is thence evident that they must of necessity be pervious to some Fluid, which being thus obstructed causes all the foremention'd Symptoms.

3 All the Nerves pass out of the cranium with a considerable Incurvation; but the nerves of the Heart, on whose Motion depend all the Actions
of

of the human Machine, run in a straight Course betwixt the Aorta and pulmonary Artery; the recurrent Nerve particularly is inflected round the subclavian Artery, and then returns upwards out of the Thorax. *Lower* observes, that the spinal Nerves descend from the Medulla, and after they have made some Progress they are again reflected upwards; but notwithstanding all these Incurvations and Inflections, we see that the Nerves continually move the Parts, and perform their several Offices; which they cou'd not do, if they acted in the manner of tense Chords; for to perform musical Oscillations or Tremors, the Chords must be stretch'd in right Lines without touching other Bodies, otherwise their impulse will not be duly propagated.

* Formerly *Galen*, and latterly *Bellini*, have made curious Experiments with Ligatures upon the Nerves of Brute Animals; from whence it appears, that if the crural Nerve of a Dog be denudated, and then tied with a broad Ligature or Piece of Tape to avoid cutting the Nerve, all the Sense and Motion of the Part below the Ligature to which the Nerve belongs, is soon after destroyed; nor will the Sense and Motion return again after the Ligature is remov'd, without the Nerve be treated with warm Applications: The Nerve is not therefore a tense Chord, for that will give a Sound, tho' a false one, tho' you make the strictest Ligature on it. But you may make the same Experiment with much more ease in your own Person, without the Trouble of repeating it in the manner before described on a living Brute; for if, as you sit, the Ham of one Leg be laid over the Knee of the other, by continuing in that Posture for some time, and compressing the Nerve, you will no sooner attempt to rise up, but a Numbness or pa-

alytic Disorder is perceived in the Limb, which has a painful Sensation, popularly known by the Name of one's Foot being asleep, which Symptom gradually vanishes in a little time after the Nerve is set at Liberty from the Pressure.

So that every Moment a Person is alive and well, the Blood is impell'd from the Heart to the Cortex of the Brain, and its thinner Juices being attenuated in their Passage thro' the several Series of the Vessels in the cortical Fabric, are at last transmitted in the Form of a most subtile Liquor into the medullary Tubuli; from whence it passes in an uninterrupted Course into every individual Part of the Body by the Nerves. To corroborate this Doctrine, we may add the experiment of *Drelincourt*, who having made a Ligature upon the carotid Arteries of a Dog, he fell down suddenly apoplectic, nor had he any Sensation without relaxing the Ligature. I am sensible that this System is oppos'd by several specious Arguments and Difficulties urg'd by those who deny the Existence of a nervous Juice; but I am fully persuaded that every rational and unprejudic'd Person, who duly considers and connects the several Principles which we have before advanced, will find no Difficulty in this System of a nervous Fluid.

§. 285. There is therefore no Face of Truth in that Opinion, which asserts the Nerves to perform all their Actions by Vibrations, like those which arise from striking a *tense*¹ Chord or Threat: Since this is repugnant to the Nature of the soft, pulpy and flaccid Nerves (§. 284, (4).) which have so many Inflections and Incurvations; and also inconsistent with that very *accurate*² Distinction with which
Objects

Objects are represented to the Senses, and with which the *muscular* Motions are performed.

Thus, says they, a Motion may be communicated from the Brain to any particular Part instantaneously, in the same manner as a Vibration is propagated from one Part of the tense Chord to the other without any sensible Interval of Time, or as the Motion of the Hand is govern'd variously in the smallest Instant to direct the Sword or Cudgel, which they think is hardly intelligible upon any other Principle than that of Vibration; but these Gentlemen do not consider the Impossibility of such Oscillations in the Nerves, which without their Integuments are nothing more than a soft Medulla, so yielding, that an Ounce Weight will express all the pulpy Substance which the optic Nerve received from the Brain; but for a Body to be soft and flaccid like a Pulp, and to perform Vibrations like a tense Chord at the same time, is quite opposite to the Nature of Things, and are Conditions that were never yet observed in any one Body. But to mollify this Objection, some of them will reply, that the Nerves receive their Elasticity and State of Tension from the Meninges with which they are invested, and which are apparently elastic, as they are continued with the Nerves to the several Parts of the Body, and occasion them to contract or shrink up, after any Wound or Division; but they ought again to consider, that these Coats make no Part of the Nerves, so far as they are Organs for Sense and Motion, but only serve to convey and secure them in their Course to the several respective Parts, where they are at length deposited as useless to the medullary Substance of the Nerve itself, which alone is the Instrument productive of Sense and Motion. Add to this, that if we suppose the Nerves

stretch'd like tense Chords, they wou'd be incapable of performing their Offices; for the most elastic Chords will neither tremble nor perform musical Oscillations, if they are either inflected or in so lax a State as the Nerves.

² The optic Nerve expands its medullary Substance for Sensation in the Form of a Cup, which is continued from the Center of the optic Nerve to the ciliary Processes; but if we suppose this to be a solid and tremulous Cup or Glass, I say that if one Point be struck all the rest will be likewise put in Motion; for the Tremor of a solid and continuous Body propagates itself throughout the whole, so that every Point of the Eye would thus be sensible of but one Object, whereas we see an infinite Number very distinctly at one and the same Instant, each Object acting on a different Part of the Retina, and conveying its Impression distinctly to the Brain, which could not be effected by a tremulous Solid.

³ I am not ignorant that *Swammerdam* has oppos'd Experiments to this Opinion, and has demonstrated that by compressing of the Nerve belonging to any Muscle of an Insect, that Muscle will be convuls'd; and *Steno* having divided the crural Nerve in a Dog, found that by vellicating and pulling the same the Foot was directly convuls'd. Add to this, that Vipers and Snakes of all kinds continue their reptile Motion after the Heart has been pull'd out; and a Frog that has had its Heart and Lungs cut out will swim upon being thrown into cold Water, also an Eel being cut into several Pieces continues to move about for a long time after; but all these are in Reality no Objections to the Existence of a nervous Fluid; for the two first Experiments make nothing against us, and the rest only shew that the Fabric of the Nerves

Nerves in cold amphibious Animals is different from that of the Nerves in Quadrupeds and hot Animals; so that no Argument of Force can be thence drawn to make any Conclusion with regard to the human Body.

§. 286. In the same manner therefore as the arterial Blood and Lymph are perpetually distributed or moved into all the vascular Parts of the Body, so we also understand that the Juice separated by the Cortex of the Brain and Cerebellum is continually *propell'd* from thence through the Nerves by the Force of the Heart and Arteries into every individual Point or solid Particle throughout the whole Body.

And at length returns again from all Parts of the Body to the Spring from whence it came, to wit, the Brain; so that that Part of the oily subtile Liquor which is separated from the Blood in the cortical Substance of the Brain, and pass'd from thence through the Tubuli of the nervous System into every even the minutest Part of the whole Body to the very smallest Stamina, are at last absorbed and returned by very minute nervous Veins opening into the visible lymphatic Veins; from whence passing into the lymphatic Cava, *i. e.* the thoracic Duct, it goes from thence into the sanguiferous Veins, and so to the Heart, which again sends it to the cortical Substance of the Brain, to be there separated afresh and repeat the same Course many times successively; so that there seems to be a Circulation of the nervous Juice not unlike that of the Blood and other grosser Humours of the Body.

§. 287. Lastly, the exceeding Subtily of the vascular Tomentum of *Ruyfch* in the Cortex, (which is yet only the groffer arterial Fabrick sending off lateral Branches, decreasing gradually till they become inconceivably fine Emissaries) teaches us how very minute or slender those hollow Threads, or soft Tubuli of the Nerves must necessarily be; but if the vast *Bulk*¹ of the Encephalon be again compared with this Minuteness of the nervous Tubuli or Fibrills, it demonstrates them to be more numerous than can be conceived within the Bounds of Imagination; and that the vast Quantity of Juice forcibly propell'd hither must inevitably keep those Tubuli constantly open and full for Action.

¹ There is not any one Viscous in the human Body equal in Size to that of the Brain and its Appendages, to wit, the Cerebellum and Medulla Spinalis conjunctly, which is the larger still as a viscous, since there are no Incumbrances from large Blood-vessels, Fat, or other Embarrassments being only a Composition of the minutest Vascules from which the Medulla immediately arises; which, being so much smaller than the sanguiferous Vessels, admits of a much larger Number to be wound up in the same or a less Space. 'Tis true the Injection of *Ruyfch* penetrates into the second or third Series of the arterial Vessels in this Part, but then the greatest Part of the Cortex remains still unentred by the Injection. The Lungs consist almost entirely of Air-vessels, and if you wash out the Blood by injecting Water, then force out the Water

ter by pressing Air into them, and at last dry them, the whole Substance of the Lungs appears empty Membranes, replete with Air only ; even the Liver, notwithstanding its great Bulk, would be incapable of filling the cavity of the Spine and Cranium if you consider the Figure of the last, and deduct the large Vessels which add little or nothing to the Secretion ; but if the Liver thus appears less than the Brain and its Appendages, you will readily give up all the other Viscera which are much smaller. To conclude then, if you consider the vast Bulk of the Brain, and compare it with the incredible Tenuity of its Vessels, it will readily appear that the Number of secretory Tubuli and Vasculæ therein must be infinite, and that these latters are continually and equably pervaded by a most subtile Juice.

§ 288. But we are in the mean time persuaded that this Juice does not move with any great *Force* ¹ through its proper Tubuli or Vessels, if we consider the infinite Number, Minuteness, Incurvations, and Contexture of the small Arteries through which it is strained ; on the contrary, the vast Number, subtil Divisions, various inflections, and different Compactness of the Nerves in different Parts, prove the Flux thereof to be constant, gentle, and *equable* ².

¹ The Juice of the Nerves flows through them continually, but not with a violent or rapid Motion ; for the Flux of all the Juices throughout the whole Body results from the impelling Force of the Heart and the elastic Contractions of the Arteries, which being strongest in the largest or first Series
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of Vessels, to wit, the sanguiferous, gradually weakens as the Juices are thereby protruded thro' the several lesser Series of ferous Vessels, into which the Force of the Heart is scarcely extended; but the Serum and Lymph are rather protruded by the arterial Contractions, which being still less as they diminish, are divided into lesser Series, the last Series of them will be so small and unactive as to protrude their contents very weakly and slowly, so that the Velocity of the Fluid will be continually diminished as it passes from the Heart to the Entrance of the nervous Tubuli or Medulla of the Brain, having communicated almost all their Motion to the several other Juices and Impediments which they meet in the way; but the Nerves are the very smallest Series of Vessels, and being the remotest from the Heart, the Impetus and Velocity of their contained Fluid will be less than in any other Vessels; and it is necessary it should be so, if we consider the very tender and pulpy Substance of the Cortex and Medulla, from whence the soft Substance of the Nerves is continued; which is again another Argument for a very slow Motion of their contain'd Fluid. It cannot be said with Justice that there is a Mechanism in the Brain to accelerate or quicken this slow Motion of the nervous Fluid; for the large arterial Vessels there, which protrude the Lymph in other Parts of the Body, have here little or no Motion from the Thinness of their Coats, being like those of small Veins; nor can we expect any such Impulse from the Motion of the Dura Mater, as *Pachioni* and *Baglivi* have imagined; for the Dura Mater closely invests the Cranium, and is so strictly attach'd to the Bones that it cannot recede from them in the least, insomuch that its Arteries are rather forc'd to make their Impressions upon the Bones themselves

selves by the strict Adhesion of this Membrane. But it does not follow, that because the Motion of this Juice is slow that therefore its Action must be so, for we are assured to the contrary, by its instantaneous Obedience to the Will in Dancing and other Exercises; the Mind no sooner wills the Extension of the Arm but it immediately follows; not because a certain Quantity of the nervous Juice is impell'd at that time all the way from the Brain into the extended Muscles, but because all the nervous Tubuli being full, an Impulse communicated to the Liqueur at one End of the Tube will thrust out its Globules at the other End in the very same Instant of Time; as we know by placing a Row of ivory Balls close to each other upon a Table, and then by striking upon the outermost Ball at one End, the furthestmost at the other End will instantly recede or run off with the Velocity first communicated, without any sensible Succession through the intermediate Balls; and if a Tube be full of Liqueur, you no sooner urge more in at one End but it instantly runs out at the other.

² This is an Objection, which, upon mature Consideration, may be easily obviated by any one, thus; If the Motion of the Heart be alternate with Intervals of Rest betwixt each Contraction, then the Motion of the nervous Fluid resulting from that of the Heart will not be equable and continual, but impeded alternately by Stops whenever the Heart dilates; but we know that the Senses are continually maintain'd, and therefore the Flux of the nervous Juice must be equable and uninterrupted through the Nerves, contrary to the Drift of this System. But this Difficulty is easily removed if we consider that the nervous Juice moves in its contained Vessels like the Blood in the Arteries, which never cease to protrude their Contents
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though they do it with an unequable Velocity; the Motion of the arterial Blood being accelerated as often as the Heart contracts, and in the same manner, I suppose, that the Sensations are perpetually maintained, but more exquisite when the Blood is impell'd into the cortical Fabric of the Brain. Agreeable to this *Malpighi* observes that the Light which he perceived as he lay in Bed was not equally vivid all the time, but made with Flashes or sudden Starts of Brightness whenever the Heart contracted itself; 'tis certain the Light itself was the same all the time, only it made a more vivid Impression on the Nerves when they were fullest; whence it is probable that the Impulse or Motion of the Juice in the Nerve is continued from that of the Blood, but is sometimes accelerated and retarded like the last, only the Difference is not sensible, because the first Impulse or Augment of Motion is very little impaired before it is succeeded by a second and a third, &c.

§. 289. From what has been said you will therefore hardly wonder ¹ that the Motion and Existence of this Juice cannot be seen, nor that it cannot be exhibited to the Eye either by *Ligatures* ², *Wounds* ³, *Punctures*, *Suction*, the *Air-pump* ⁴, or *Injections* ⁵; for whoever expects or attempts at these Methods of Discovery, must be ignorant both of the Nature of the Juice and its containing Tubuli: But they who deny the Existence or Perviousness of small Vessels because their Cavities are not demonstrable to the Eye, must be such as are highly ignorant of the original Mechanism of our *Bodies* ⁶ at first, of their After-growth or
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Increase, and of the several animal Operations and *Excretions* ⁷; they must also know nothing of the Fabric of *Insects* ⁸, nor have taken any Notice of what may be manifestly observed in Plants.

¹ There have been several eminent Gentlemen in the Faculty who have thought it apparent there was no animal Spirits or nervous Juice, because none could be exhibited to the Eye. I am indeed myself of Opinion that the Art of Physic ought to be founded on none but sensible Experiments; but then I think we ought not to deny our Assent to such evident and reasonable Conclusions as apparently follow from sensible Phænomena. Before *Lewenboec* invented microscopical Lenses of the sixth Order, there was no one that could demonstrate to our Senses or Eyes that the sanguiferous Arteries and Veins were continuous with each other; but you must allow it would have been very rash and hasty in any Person to deny their Communication, or the Blood's Passage from one to the other, because none such could be then shewn to the Eye. The Pulse is evidently perceptible in the Artery upon its Dilatation from the Blood by the Heart; but no one will deny the Pulsation, which can only be felt, because he does not see it, for all we can see is the Dilatation of the Artery in the Instant only when the Blood is impell'd from the Heart. In the same manner we cannot see the nervous Juice, but we see the Brain and Nerves all grow and increase in Proportion with the Heart and rest of the Body, and therefore conclude that the Brain and Nerves are replete with a Juice which they continually receive from the Force of the Heart. We ought not to invoke the Testimony of our Senses to prove the
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Existence of these Spirits; for as *Aristotle* wisely observes, we are not able to see that which sees, nor hear that which hears; even to do this would require us to have our sensitive Organs so exquisite or subtile that they would be incapable of perceiving the external and gross Fabric of Bodies; and then it was altogether necessary for the Liquor itself which receives the Impressions of Objects to be so fine as not to make any Impression on the Organs, otherwise the Mind would perceive the included Liquor instead of the external Object, and therefore it was not possible for any visible Liquor to be capable of performing the Office of a nervous Spirit.

² It is urged by some, as a strong Argument, that if you make a Ligature on the Nerves, they do not swell betwixt the Brain and the Parts to which they belong, and that therefore they do not carry any Liquor from the Brain into those Parts; but this in fact demonstrates no more than that the nervous Tubuli are exceeding small: For no one could ever demonstrate the swelling of a lymphatic Artery by Ligature, when it is notwithstanding a real Artery, and an infinite Number of times larger than any of the nervous Tubuli.

³ There have been formerly some eminent Professors in this University, who endeavour'd to prove publickly by Experiments, that the Nerves were solid Bodies without any Cavities in them. In order to this they took the auditory Nerve, and with a Magnifier endeavour'd to observe, whether or no they could distinguish any Foramina in a transverse Section thereof, or whether they could perceive any Juice run out from the Division; but every unprejudiced Student denied that they could see either, whereupon the Professor triumphs and gains the Victory over the controverted Spirits.

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But for my own Part, I must declare my Surprise at the Levity of such Men, who are ready to draw Inferences and Conclusions any way, just as they are pleased to think. 'Tis well known that nobody could ever discern the constituent Particles of pure Water, even by a microscopic Lens of the sixth Order; and therefore by this Rule the Water must consist of no Particles because they are not visible. If a Vessel of extravasated Blood be set by in a warm Place, the Mass will gradually diminish till it is at length wholly exhaled into the Air; but as you can never discern any of the exhaling Particles by the Microscope, you must thus therefore conclude there are no exhaling Particles, when at the same time the whole Mass evaporates in such. From one of the Seeds of the Gourd, which the *Italians* call *la grossa*, arise very large green Leaves, and such Fruit that one of them weighs above eighty Pounds, and some of them have been sent to the Count *Marsigli* weighing a hundred and twenty Pounds: But all this Mass or Weight of the Fruit has run through the Peduncle or Foot-stalk no thicker than a Goose-quill within the Space of sixty Days, notwithstanding no Tumour will be form'd betwixt the Root and Peduncle, after making a Ligature on the last; but it is nevertheless vascular, and *Ruyseh* has demonstrated that there is not one Tube or Vascule in the Fruit which was not before in the Peduncle. Even the eighty Pounds of Juice in the Fruit is but a little Part of the whole Quantity which passes that way; for one of those Gourds soon loses above twenty Pounds Weight of its Juices by Transpiration; nor did it perspire less whilst growing than after it has been gathered: So that if we only make the Weight of the perspired Juices equal to that of the Gourd, the Amount will be a hundred and eighty Pounds; of

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which three Pounds must have passed daily thro' the Peduncle, since there is no other way for it to pass, as appears from wounding or dividing the said Peduncle, which will not then produce any Gourd; but this Peduncle could not transmit so many Pounds of Juices without being full of pervious Tubuli to convey them, and notwithstanding if you tie and cut the Stalk, or endeavour to draw out the Juice by the Air-pump, all will be found to have no Effect in demonstrating those Tubuli.

4 A certain Professor suspended Part of a large Nerve in the Receiver of an Air-pump, but upon exhausting the Air no Juice could be extracted from it, and he therefore thought this was an evident Proof that the Nerves did not convey any Liquor. But suppose the Juice of the Nerves as gross as the common Air, do you think that Air could be perceived issuing out of the Body in an exhausted Receiver; but the nervous Juice is probably finer, more pellucid and less visible than the Air: Even the nervous Tubuli seem to be so small, that upon dissecting them any way, neither their Cavities nor Juices can be discerned by the sharpest Eye.

5 Some will say if we can inject other very small and naturally invisible Vessels, so as to render them conspicuous, why not the Nerves also, if they are pervious; to which very weak Objection we answer, that the smallest Vessels ever injected are probably some Millions of Times less than the nervous Tubuli.

6 We grow up from a Point next to nothing, even to that Bulk in which we at present appear; and yet in that small and invisible Point were comprised all, and even more Vessels than we have at present: Since we observe all the same Arteries in

a Fœtus as in an Adult, in which last there are many Parts which were Vessels in the Fœtus but are not so in the Adult (*per* §. 467.). But all this invisible and human Animalcule is at first like a fluid Mucus; and if you therefore assert it has neither Arteries, Veins, or Nerves, you will contradict what we have proved to be true in §. 673; but if you say it has Veins, Arteries, and Nerves, are they therefore visible?

⁷ Through the hard Cutis covered with the horny Cuticle, exhales daily five Pounds of the perspirable Matter of *Sanctorius*; but *Lewenboec*, with his best Microscopes, could never discern the exhaling Particles; for what he observed transude through the Skin was only an oily Matter. Who will demonstrate those odorous Particles to the Eye, which flying off from a Person's Skin and Cloths, and adhering to adjacent Bodies, serve as a faithful Clue to conduct the wandering Dog through the Meanders of a populous City to his lost Master? yet is the Existence of those Pores and Particles not the less certain because invisible.

⁸ *Lewenboec* inspecting some fresh and pure Rain-water, could at first distinguish nothing therein; but after standing a few Days the Water grew foul and turbid, and in it appeared an infinite Number of little Fish of various Kinds. Among these Animalcule there was one consisting of thirty Joints, perpetually turning and winding itself about, and at last deposited a great many Eggs, from whence arose more Animalcules like the first; but for the Motion of these there must be Nerves, Muscles, Arteries, &c. Let not any Body therefore deny the Existence of every thing they cannot see, since there are whole Animalcules, the most complex Machines in all Nature, escaping the sharpest Eye.

§. 290. But it is even a still groffer Error to imagine that the very thick, viscid, and *lymphatic Juice*¹ which issues from the Nerves of an Ox's Tail that has been cut off, is that very fine Spirit or Juice of the Nerves we have been now describing : Nor can any Liquor *injected*² by the carotid Arteries of an Animal, so as to tinge the Nerves, demonstrate their Cavities or Tubuli : Nor does that *Tumour* which arises after making a Ligature on the Nerves of a young Animal, prove the proposed Argument.

¹ The Existence of a nervous Juice has been as lamely defended by some of its Patrons, as it hath been weakly opposed by many of its Adversaries : It even makes me blush to mention the Error of the honest and otherwise judicious *Malpighi* and *Bellini*, who both tell us, that after cutting off the Tail of an Ox or Cow, there distils from thence a nervous Juice, thick, glutinous, and apt to harden ; for the Juice here mentioned is no more than the Mucilage from the Articulations of the Vertebræ which compose the Tails of brute Animals, serving to mollify the Ligaments connecting the Vertebræ to each other.

² There have been some *English* Anatomists who imagin'd that they had deliver'd or demonstrated the hollow Tubuli and Cavities of the Nerves, because by injecting the carotid Arteries with Urine colour'd with Ink, they found all the Nerves of the Brain tinged with that very penetrating Liquor, and upon dividing any one of them transversely, they appeared full of black Specks or Points, which they supposed to be the Cavities of
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the nervous Tubuli, but were in Reality no more than the divided Arteriolæ spent upon them from the Carotids (*per* §. 235 and 282.); but those small Arteries spent on the Coats of the Nerves, and tinged with the injected Liquor, are some Millions of Times larger than the medullary Fibres or Tubuli of the Nerves.

3 Dr. *Willis* endeavouring to refute the Opponents of a nervous Spirit, urges an Experiment which at the first Appearance might seem next to a Demonstration; and that is, if you make a Ligature upon the Nerves of Whelps or other young Animals they swell betwixt the Brain and the Ligature; but then in Reality this is no Tumour or Turgescence of the Nerve, but of the Integuments or including Membranes, furnished both with sanguiferous, serous, and lymphatic Arteries, whose contained Juices being obstructed by the Ligature occasions the Tumour,

§. 291. This Liquor being very subtile, perfectly simple, fluid and volatile, is therefore termed the *Spirits*¹ of the Nerves, which are, from their Offices, distinguish'd into *natural*², vital, and animal, as we shall see hereafter.

¹ We chuse to call them by the Name of (*πνευμα* or) Spirit, after *Hippocrates*, who by that Denomination understood a Fluid capable of exerting considerable Forces, without being visible, like the Wind: And when he divides the human Body into Parts containing and contained, he includes the Spirits among the latter, which were secured and governed by the Mind as by a Door-keeper.

* The Moderns have rejected the Distinction made by the ancient Physicians of the Spirits into natural, vital, and animal ; but I think they have done this without due Consideration : For 'tis probable that the Spirits of the Brain are different from those of the Cerebellum, since their Fabric is different from each other ; and we are even furnished with Arguments to prove that the animal Faculties result from the Action of the Cerebrum, and the vital from that of the Cerebellum. Therefore the Spirits of the Brain may be not improperly termed animal, as those of the Cerebellum may be called vital : And for the natural Spirits, those may be so call'd which flow through the minutest Tubuli of the very last Series of Vessels, arising not from the Brain, but intermediately from the sanguiferous Arteries themselves throughout the whole Body ; which last Juice or Spirit is neither subservient to Sensation or Motion, but to nourish and repair the smallest Vessels and Fibres in the Body.

§. 292. But since *new* ¹ Spirits are supply'd every Moment from the Blood, the last made will drive forwards the preceding, which having performed their ultimate Uses, seem to be finally impell'd into the smallest lymphatic Veins of the Glands and other Parts, from whence passing into the lymphatic Veins of a little larger Size, and from them into the common and visible Lymphatics which have Valves, they are at last returned into the Blood of the sanguiferous Veins, and by them to the Heart, so that this Juice or Spirit has a perpetual

petual Circulation through the Vessels like the rest of the Humours.

▪ The nervous Juice is pressed or moved slowly and constantly through the nervous Tubuli by that Impulse of the Heart which is communicated from the Blood through the several decreasing Series of Vessels in the Cortex, by which it at last enters and passes through the very ultimate or least Series of Vasculæ contained in the medullary Tubuli of the Brain. This Liquor must therefore have some Exit from the nervous Tubuli, or else it would be perpetually augmenting: But we assign it a threefold Exit, as (1.) when a Nerve having ramified itself in the least Branches, spends itself upon the Stamina, or least and most simple Fibrils of the Body, and then being reflected back from those Stamina, and gradually enlarging, composes a sort of spirituous Veins, the least of any in the Body; which least Veins conveying the nervous Juice into the next larger Series of pellucid Veins, passes thence into a third Series, so into the lymphatic Veins, which open into the sanguiferous Veins, and return their Contents to the Heart with the red Blood, which seems to be a Course much more probable than for the nervous Juice to return back again to the Brain. (2.) All the internal Membranes which invest the several Cavities in the human Body [termed *Κοιλίας*, Caverns or Cases, by *Hippocrates*, which he says are fill'd either with Spirits in healthy Bodies, or with Ichor in diseased Habits] are perforated with very minute Ducts of various Kinds, some of which seem to be continued from the nervous Filaments to exhale their redundant Juice in Form of Vapours, to lubricate the Membranes and prevent their Concretion; in the same manner as the arterial Lymph transudes thro'

the Membranes of the Heart into the Pericardium, But then these exhaled Spirits or Vapours are neither condensed nor retained long in those Cavities, but are quickly again absorbed and returned into the Blood; for in the Ventricles of the Brain there is less of this Liquor to be found in Proportion as the Animal is more lately deceased, and as it was more healthy before Death; and if ever it stagnates or is accumulated in the Ventricles in any Quantity it never fails to produce either an Hydrocephalus, Apoplexy, or Lethargy. It is therefore evident that those Spirits or Vapours are absorbed by the smallest Veins, and by them returned through several Series into the Lymphatics, and so to the Blood; so that we have here two Ways by which the nervous Juices return again to the Heart, for to make repeated Circulations without being wasted or destroyed. (3.) Lastly, some of the ultimate Ramuli or Filaments of the Nerves seem to open through the Skin and exhale some of their contained Juice, every way forming a spirituous Transpiration, as we know there is an arterious one: The threefold Termination of the Nerves before described is confirmed by Termination of the Arteries in the like threefold manner (§. 132. N^o 15, 16, and 17.).

§. 293. But if you ask which seems to be the most probable Opinion, whether this Juice finally stagnates in *blind*¹ or impervious Ducts? Or whether it does not rather flow back again to the *Source*² from whence it first came? Or lastly, whether one should not rather imagine it all *exhales*³ out of the Body? I answer, that in Reality hardly either of these seems likely to be true,

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¹ There have been some Professors who have built their System of Physiology upon a Supposition that the nervous Tubuli are impervious and turgid with Spirits, performing their Actions by mere Undulations; but that is repugnant to the constant Influx of the Spirits, which would inevitably burst their soft including Tubuli, or else distend them to an immense Bulk, if they were not pervious, so as to give a free Passage to them continually; and there does not seem to be the least Foundation for supposing that they return again to the Brain by the same Tubes which distribute them from thence.

² An *Italian* Physician, *Mistichelli*, has endeavoured to prove a Reflux of the nervous Juice, by an Observation he made on the auditory Nerve, which he imagined might be plainly seen to pass through the Cochlea and Canalis Semicircularis, and then to return again to the Brain from whence it came; but it does not seem probable that the Auditory Nerve becoming a soft Mucus in those Cavities should be compacted again into a Nerve, nor is it confirmed to be so, either by anatomical or microscopical Experiments, and therefore we think that the Notion ought not to have any Credit paid to it.

³ Not that all of it exhales this Way, for neither are all the Nerves distributed to the Skin, nor could we support so great a Discharge, since it is required to be made from the Blood and Chyle.

§. 294. The Blood having been *drained* ¹ of its Spirits, secerned from it in the Brain and Cerebellum, is then impell'd into the Veins of those Parts, by which Veins it runs from every Quarter of the Encephalon in opposite Courses,

Courses, both forwards and backwards, into the *large*² venous Receptacles termed Sinus's, thence passing, at a Distance from the Fellow Arteries, through proper Holes of the Cranium into the venous *Sacculi*³ or Protuberances, and from thence to the *internal*⁴ Jugulars, so to the Subclavians, and by the Cava to the Heart.

¹ That Part of the Blood which does not enter the cortical Substance of the Brain, passes into the small sanguiferous Veins of the Pia Mater; while the more subtil Parts of the Blood which enter'd the pellucid Arteriolæ of the Cortex descends to afford the proper Matter for Spirits: But as there are no sanguiferous Arteriolæ in the Cortex, so there are not any sanguiferous Veins there; nor does the Blood pass immediately from the sanguiferous Arteries of the Pia Mater into the Sinus's without the Intervention of Veins.

² 'Tis a Mechanism peculiar to the Brain to have large venous Receptacles, of a different Figure and Make from any of the Arteries and Veins: And the Design of them seems to be to prevent any Inequality in the Motion or Course of the Blood returning from the Encephalon, which would have been unavoidable if the Arteries had accompanied each other in the Cranium as they do in other Parts; for as the cerebral Arteries are soft, and have their Tunics much like Veins, they would easily become so turgid, from various Causes, as to compress the Veins if they lay near each other, whence the Brain would have been much more liable to Apoplexies than under the present Circumstances. The Creator has therefore wisely contriv'd large venous Receptacles of a very robust Fabric,

§ 295. *Veins of the Encephalon.* 331

Fabric, and placed them at a Distance from the Arteries, so that they cannot be distended as to compress the Brain, for their Integuments or Ligamentary Fibres are so tough and very little elastic that they will sooner break than give way; but these Sinus's are inserted oblique into the Veins, and are also furnished with Valves, lest the Blood should return from the Sinus's into the Veins of the Pia Mater; and it is on the Account of these Valves that the Veins of the Pia Mater are so difficultly inflated by the Sinus's.

3 Which are four times as large as the lateral Sinus's inserted into them; by which the unequal Motion of the Blood, whenever that happens in the Brain, is necessarily abated, since these Sacculi or dilated venous Sinus's are lodged in immutable bony Cases. To these jugular Veins is conveyed all the reflux Blood of the Encephalon, not excepting that of the large Veins, which pass out thro' a particular Foramen of the Cranium, and at last terminate in the Jugulars.

4 Which are placed secure from any Compression by the Muscles, and do not protrude the Blood by the common Force of the Heart; but when the Heart is relaxed and empty, the Blood of the Jugulars finds a ready Entrance, and is every Way secured from Compression. But there is a Valve placed at the Entrance of the jugular Vein into that of the subclavian, lest the Blood should be forced out of the latter into the former, when it is obstructed in passing thro' the Lungs, as when a Person laughs.

§. 295. In the mean time the *Lymph* of the Encephalon, like that of all other Parts, being secreted from the arterial Blood thro'out the

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the *whole* ² Cerebrum and Cerebellum, is all returned, together with the Lymph that transfused into the Ventricles; and entering the lymphatic Veins proper to the Encephalon, *Infundibulum* ³, and pituitary Gland, comes at length into the Jugulars, and at last to the Heart. So that there is also a perpetual Circulation of Lymph throughout the Encephalon.

¹ Or the moist Vapours with which all the Membranes are lubricated, and with which all the Contents of the Cranium are bedew'd; which Vapours are even easily perceptible to the naked Eye when the Cranium of a living Person is trepanned; for in that Operation Vapours exhale from the whole Surface of the Brain.

² That is (1.) those Vapours betwixt the concave Surface of the Dura Mater, and the convex Superficies of the Pia Mater, which prevent the Concretion, or any Adhesion of those Membranes, mollify and relax their Vessels, and expedite the Circulation through them. (2.) The Vapours betwixt the Hemispheres of the Brain above the Corpus Callosum. (3.) The subtile Dew which transfuses throughout the whole internal Superficies of the anterior Ventricles. (4.) Where the posterior Lobes of the Brain are supported over the Cerebellum, and distinguished by the Cruciform Production of the Dura Mater. (5.) In the fourth Ventricle where the Medulla of the Brain and Cerebellum meet with each other. (6.) In the Basis of the Cranium where the investing Dura Mater sustains the Basis of the incumbent Brain.

³ The Infundibulum is one of the Emissaries of the Ventricles, which was first taken Notice of by
Lower.

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Lower. From the second Ventricle the Vapours are condensed and convey'd to the third, and from thence they descend by the medullary Infundibulum to the pituitary Gland, where being absorbed by the Veins, they are by them returned into the Blood. But these Vapours do not all arise from one Part of the Brain only; for Dr. *Ridley*, who has in the Anatomy of this Part cautiously endeavoured neither to deceive himself nor others, demonstrates that a great Part of the Plexus Choroideus is composed of pellucid and valvular Veins, which are in Reality mere lymphatic Vessels, discharging their vapoury Dew and Juice into the fourth Sinus, from whence passing to the lateral Sinus's they at length return by the jugular Veins to the Heart. And these are the two principal Ways by which the moist Vapours or lymphatic Juices of the Encephalon are naturally absorbed and returned into the Blood. But if this Moisture is any way retained and accumulated, it is follow'd either with a Lethargy or Apoplexy: And sometimes it has been found retained to the Quantity of two Ounces.

§. 296. From what has been hitherto said on this Viscus we are enabled to answer to the following Questions: As why the Cerebrum and Cerebellum, with their Appendices, are defended with a *Case of Bones*¹, and what Advantages result from that Defence? Why the *whole*² spinal Medulla is lodged in the Chain or Case of Bones termed *Vertebræ*, and without the Incumbrance either of *Muscles*³, Glands or *Fat*⁴? Why the carotid and vertebral Arteries never convey the *red*² Parts of their

their Blood into the cortical Substance? But spend their sanguiferous Branches *only*⁶ upon the Surface of the Pia Mater, and betwixt the winding Ridges and Furrows of the Encephalon? And why those Arteries do not run together with their corresponding Veins, but take a *different*⁷ Course and pass through distinct Holes of the Cranium? Why the venal Blood of the Encephalon is returned into particular Sinus's, and why it does not again pass strait forwards in those Sinus's? Why the sanguiferous Veins, being very much distended, are never observed in the Cortex, but are spread only on the *Superficies*⁸ thereof and insinuated in the Furrows betwixt its Gyri? Why those Veins discharge themselves immediately in opposite Directions into the *Sinus's*⁹? Why a thin and *black colour'd*¹⁰ Liquor being forcibly injected by the Carotid, and even broken Threads of the ceraceous Injection itself, are sometimes found in the Cavity of the superior Sinus's? And whether they do not enter these Sinus's because the Arteries of the Pia Mater communicate by patulent Anastomoses with the Veins opening into those Sinus's, and into which the Injections pass? Why the Cavities of the Sinus's are strengthened by muscular Threads or transverse Ligaments? Why the Encephalon is *spherical*¹¹, with the Use and Necessity of the *Ventricles*¹²? The Composition and Use of the Plexus *Choroides*¹³. The Uses of the *Falci-form*¹⁴, and other Processes of the Dura Mater.

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ter. Why the *Cerebellum* ¹⁵ is without Ventricles, and placed by itself, more secure than the *Brain* ¹⁶? Why the soft Nerves are not *compressed* ¹⁷, but pass out freely from the superior Mass of the Brain and *Cerebellum*? And lastly, whether the *Origin* ¹⁸ and Termination of all the Nerves is in the *pineal Gland* ¹⁹?

▪ We know of no other Part of the Body that enjoys this Privilege besides the Brain and its Appendages, with the Marrow of the Bones. But the Resistance and Stability of this Case of Bones, the Cranium, occasions the Brain never to shrink or waste even in Consumptions; and prevents it from enlarging at any time. And the spinal Medulla standing in need of the same Defence, is also deposited in the Cavity of the Vertebrae, a Chain of Bones which not only defend and secure their tender and important Contents, but are also movable at the same time by a surprising Mechanism of Articulations and Processes; the spinal Processes at the same time preventing the Vertebrae from receding so far from each other, as might expose the spinal Medulla behind.

² The Cortex and Medulla of the Brain are of so tender and soft a Texture, that the least Force wounds or dissolves them; and therefore it was absolutely necessary, as well from their Fabric as important Uses, that they should be thus guarded from all external Injuries.

⁴ As the Action of the Muscles is neither constant nor equable, but alternate and violent, if the Brain had been exposed to their Pressure, all its Juice would have been suddenly expressed and discharged without leaving any Supplies; so that the

Influx

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Influx of nervous Juice would have been alternate, as would consequently have been the Effects thereof, alternate Fits of Sensation, Motion, &c. as *per* §. 235. according to *Pacchioni*.

4 As we never observe any Fat about the Brain in a healthy State, so there are no Uses for it in this Viscus; for there is no violent Motion or Attrition of Parts to be thereby abated, nor any acrid Humour to be obtunded: Nor is there any room for Fat, since the whole Capacity of the Cranium is fill'd with the ample Cortex and medullary Substance, which to have loaded with Fat would have been followed with the most dangerous Consequences; since the Quantity of Fat investing any Part varies at different times, being sometimes more and sometimes less, whence the Brain wou'd have been at one time relaxed, and at another time compressed, so as to prove destructive to the Animal; especially some that I have often seen upon the Shambles, where the vast Muscles of an Ox was scarce perceptible, being buried in Fat. 'Tis indeed true, that *Ruyfch* has sometimes found a little Fat betwixt the Pia Mater and tunica Arachnoides; but this only in Brutes, which were hereby become quite stupid, and wou'd soon after have died apoplectic, and therefore the Appearance of Fat about the Brain is always preternatural or morbid.

5 To save room; for the only Design of Nature being the Separation of Spirits, she has therefore only supplied this Part with the smaller Series of pellucid Vessels, fit to transmit the more subtle and spirituous Parts; so that neither any of the red sanguiferous, nor any of the yellow ferous Arteries are distributed within the Substance of the Cortex.

And

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⁶ And that partly in order to communicate Heat, which is generated by the red Blood only; and partly to augment the Surface of the Cortex.

⁷ By Exercise, or an increased Action of the Muscles, Heart and Arteries, the Blood becomes so attenuated, rarified, and accumulated in the Arteries, as to distend them beyond their usual and proper Diameters, so as to compress the adjacent and less resisting Veins; and for this Reason provident Nature has placed the Veins close by the Sides of the Arteries in many Parts, where the sluggish venal Blood wants to be urged forwards in its Vessels: But if this had been the Case with the carotid Arteries, upon any Compressure or Distention of them by bending the Neck and Head in Sleep, by Exercise, Drinking &c. they would by their greater Distention compress the jugular Veins, if they passed out of the Cranium thro' the same Holes with the Arteries, whence would arise the most dangerous Symptoms, if not an Apoplexy and Death. Thus Wrestlers have some of them the Craft to twist the Shirt-collar of their Adversary so as to compress the jugular Veins, whereby his Antagonist loses all his Strength, and becomes unable to stand on his Legs. *Streno* furnishes us with an Example of an Apoplexy induced by a Ligature on the jugular Veins of a Brute; and it is the same with those who are hanged or strangled by the Executioner, for they all die apoplectic.

⁸ Because the Cruor or red Blood does not penetrate into the Substance of the Cortex.

⁹ Most of the other Veins in the human Body run by the Sides of Muscles, whose Contractions propell forwards their thick and slowly-moving Blood; but it is evident from the Mechanism and Use of the Brain, that no Muscles cou'd be admitted about its tender Fabric, and therefore another

Contrivance is used to render the Circulation free thro' this Part, *viz.* large Sinus's or membranous Receptacles into which the small Veins immediately discharge themselves. But these Sinus's are again placed so as to be free from all Compressure, the longitudinal Sinus betwixt the two Hemispheres of the Brain, and the rest in other Parts of the Basis of the Cranium, where the Inequalities of the Bones guard and defend them also from any injurious Compressure. The same Observation is also applicable to the Veins which form Rings about the Medulla Spinalis within the Cavity of the Vertebrae, being a sort of Sinus's free from any muscular Compressure, into which the small Veins of the spinal Medulla immediately discharge themselves.

¹⁰ Dr. *Ridley* has observed, that some of the small Veins proceed backwards from the Fore-part of the Brain, to open into the Sinus's, and others come forwards to their Insertion; by which opposite Insertion of the Veins their Blood suffers a Collision and Attrition of its Parts, as it is poured into the large Sinus or Receptacle, and thus its Concretion is in some measure prevented, to which the venal Blood of the Encephalon must otherwise have had a greater Propensity than that of other Parts. 'Tis also peculiar to the Veins of the Brain to meet in returning Angles, whereas the Veins of Muscles and most other Parts concur in acute Angles.

¹¹ See §. 234. Even in this Experiment we find *Ruyfch* and *Raw* agreeing, who are hardly ever of the same Opinion in any one thing besides: *Ruyfch* always found little distinct Cylinders or Threads of the Injection which had transfused into the Sinus's; which Threads of the Wax or Injection resembled those he observed in the Veins of the Pia Mater after injecting that Membrane.

Because

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¹² Because under a Surface of that Figure may be comprized a Body of the largest Quantity, and at the same time that the vascular Strata of the Cortex might be the more orderly disposed one within the other; and that the Center or Medulla might be less pressed than it would have been in any other Figure; for the Cortex being spherical, one Part of it sustains the other.

¹³ Besides what has been said at §. 272, we shall demonstrate hereafter (§. 534.) that these Ventricles conduce to the alternate Vicissitudes of Sleep and Vigilance, by a Compressure of the Medulla of the Brain.

¹⁴ The whole Plexus Choroides is a Membrane upon which a few sanguiferous and pellucid Arteries, and many more Veins, are orderly disposed and distributed within the Ventricles of the Brain; from whence the pellucid Veins absorb the transfused Vapours or Moisture of this Part, by their smallest Orifices, and then return them into the Sinus's. But these moist Vapours exist here of Necessity, because all dry Membranes fret and cohere together without them in a little time; whence we observe, that the Pleura having had its exhaling Vessels destroyed by an Inflammation of that Membrane, it afterwards readily adheres to the Lungs, and if the Adhesion be large, leaves an Asthma behind, which is inflexible to all the Medicines in the World: But were the Membranes of the Brain to adhere in the same manner, the Consequences would be much worse than an Asthma; to prevent which therefore the Choroide Plexus exhales a moist Dew by its evanescent lymphatic Arteries, which is again absorbed by the Veins. Add to this, the Plexus we are speaking of serves to communicate the Heat of the arterial Blood to the cold Medulla,

and at the same time also to promote the Course of its Juice into the Nerves.

¹⁵ When a Ball is flung on the Parchment of a Drum that is braced, it does not stand still, but flies back in a contrary Direction; and in the same manner when one Hemisphere of the Brain is by any Shock urged against the tense falciform Process of the Dura Mater, the Concussion is broke off both from itself and from the opposite Hemisphere; and this longitudinal Production of the Dura Mater also prevents one Hemisphere from compressing the other by its superincumbent Weight, when we lay down the Head on either Side. But the longitudinal Sinus serves to forward the Course of the venal Blood of the Encephalon, which is not promoted by the Pulsation of the Arteries, as it is in many other Parts (*vid.* §. 234.) The cruciform Process of the Dura Mater betwixt the Brain and Cerebellum does also answer the same Uses with the preceding

¹⁶ In this Part the Vitality of a Person more immediately resides, and therefore it is so placed as to lie secure from all Injuries but what hurt the Brain at the same time; for the posterior Lobes of the Brain extend themselves farther backward and downward than the Lobes of the Cerebellum which are placed more forward. But on the lower and Back-part the Cerebellum is defended externally by strong Muscles, which make up for the greater Thinness of the Cranium there. 'Tis also upon the same Account, *viz.* the Importance of the Cerebellum with regard to Life, that the vertebral Arteries are so well secured and defended in their Passage to it, ascending through the Foramina of the transverse Processes of the Vertebrae in the Neck, so that they are hardly ever wounded or injured.

It

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¹⁷ It was necessary for the Brain to be able to suffer such a Change, that it might perform its Actions at one time and abstain from those Actions the other half of Life; it is therefore furnished with Cavities or Ventricles, which, being empty, the Brain is in a manner relax'd, but when full it is in some measure press'd, and in a State of Tension. But the Cerebellum having no such Ventricles is therefore not liable to such Vicissitudes, but continually labours to carry on the vital Functions.

¹⁸ Because the Processes of the Dura Mater which sustain the Cerebrum are so stretched over the Protuberances in the Basis of the Cranium as to prevent its incumbent Weight from compressing the soft Nerves. The optic Nerves pass out of the Cranium under a strong Production of the Dura Mater, which serves for a Case to the said Nerves, and the other Nerves are secured in like manner. But sometimes when a Man jumps or falls down from a high Place upon his Feet in an erect Posture, the Repercussion from the Earth forces the Brain towards the upper Part of the Cranium, by the Re-action of which last the Brain is again forc'd so violently upon the Basis of the Cranium as to compress the Nerves which there arise from it, so as to render the Person stupid, or without the Use of his Senses for some time.

¹⁹ Wherever the Cortex terminates there the Medulla of the Brain begins, and so does also that of the Nerves; to wit, in the whole Circumference of the anterior Ventricles, and from every Point of the Cortex of the Cerebellum; the Origin of the first of these was observed by *Vieussens*, but he improperly named it Centrum Ovale; so that the nervous System does not arise from any one Point but from distinct Parts of the Encephalon,

lon, and their Terminations is also distinct throughout every Part of the Body.

2º No body will easily believe that the forty Pair of Nerves which come out of the Cranium and Medulla Spinalis, arise from so small a Part as the pineal Gland, which is so frequently distended, putresied or render'd schirrous in many Diseases of the Brain, without any Injury thence arising to the Senses, and which is lastly placed at a Distance from the Brain and Cerebellum. Every intelligent Person who considers these Circumstances, will not easily believe the Notion of *Cartesius*, who placed the Origin and Termination of the whole nervous System in that Gland, when at the same time the pathetick Nerves only rise near it; however it must be confess'd, that the Use of this Part is not yet sufficiently known. *Quere*: Whether its Fabrick is not like that of the Cortex of the Brain, or whether it does not serve to absorb the moist Vapours and Juices subsiding to the Basis of the Cranium in the manner of a Tunnel?

§. 297. And indeed the Fabrick of the Encephalon will evidently appear to every one who duly considers its whole Mechanism before described, to be formed with the highest and most adorable Wisdom, its Vessels being so disposed as to carry on an equable and constant Circulation and Secretion of their contained Juices; and it will also appear to be continually warmed both by the adjacent venal and arterial Blood, since the very minute and pellucid Vessels of its Composition would be otherwise destitute of Heat; and lastly, the returning Lymph will appear to meet with a ready

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ready Entrance and Commixture with the venal Blood of the Sinus's, let the Head be retained in any Posture whatever.

The medullary Substance of the Encephalon is; of all Parts of the Body, much the remotest from the Heart, the Source of animal Heat; it was therefore necessary for it to receive Warmth from the adjacent external Arteries, partly from the Dura Mater; with the numerous Arteries of the Pia Mater; partly also from the Arteries of the Plexus Choroideus with those little Arteries which descend perpendicularly from the Pia Mater betwixt the medullary Fibres: Add to this, that the venal Blood is warmer than the Lymph, and therefore the medullary Part of the Brain may receive some Warmth from the Sinus's, and from the Veins in the Plexus Choroideus.

§. 298. But the Blood having performed its Office in the Encephalon, returns afterwards diluted with the Lymph of the Brain, and mixing with fresh Lymph, Chyle, and venal Blood with the returning Bile, and perhaps Spirits in the larger Veins, it is from them received into the Heart, which propells the same into the Lungs, where it is again changed (*per* §. 200.), and puts on the same Disposition which it had before it was first sent to the Brain.

§. 299. And if no crude or indigestible Particles remain in the said returning Blood, it will all again, by this new Apparatus only (§. 298.), become the best fitted to supply fresh

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fresh Spirits again, by the Fabric of the Brain and Cerebellum.

§. 300. 'Tis therefore probable that a certain *Portion*¹ of the whole Mass of Blood (§. 224.), does thus pass to and from the Encephalon, in the Course before described, without any considerable Mixture with other Blood of a different Nature; whence it will be the better disposed to circulate the same Way again, more frequently, swiftly, and equably.

¹ That namely which is the most compact, solid, and moveable, being also replenished with the Spirits returning from the Veins, which Part of the Blood will therefore be the more apt to return again to the Brain, and to circulate through it more frequently and swiftly, since the Passage of the Blood from the Heart to the Encephalon is direct, and without any Obstruction from Fat, Muscles, or other Impediments; but as similar Causes generally yield similar Effects, and as the Blood was better disposed than the rest of the Mass to ascend to the Head at the very first Moment of its entering the carotid Arteries, by that Disposition it will also be carried rather to the Brain than to any other Part.

§. 301. Lastly, If we consider (1.) the great *Bulk*¹ of the Brain, Cerebellum, Medulla Oblongata and Spinalis, with the vast Number of large Nerves which proceed, and are distributed from them every way, and then compare the whole System with the Bulk of the other *nearly*² solid Parts of the Body;
(2.) That

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(2.) That the Encephalon and spinal Medulla are the first apparent Basis of the Carina or incipient *Embryo*³, from whence the rest of the Viscera and other Parts are afterwards produced, as we are assured by the accurate *Malpighi*; and (3.) that there is scarce any Part of the whole Body but what is invested either with the Faculty of *Sensation*⁴ or local Motion: From all these Considerations we may believe that almost the whole Mass of the solid Parts in the Body are complicated and made up with nervous Filaments.

¹ As not being loaded like other Parts either with Air, Blood, or Fat, or Muscles, but is entirely a Compages of minute Vessels, giving rise to the Nerves; with which vascular Compages is fill'd the large Cavity of the Cranium and Vertebræ, and which is in reality continued through every individual Part of the Body, by those innumerable Productions the Nerves.

² The true or compact Mass of an Animal is not such as appears to us; for, in the first Place, there is a large Quantity of Fat to be deducted, since the Animal may live very well without it and becomes more active thereby. The Limbs of a Patient who has an Ulcer in the Lungs shrink up almost to nothing, without losing any thing but their Fat and Juices, which soon return again after the Lungs have been restored to their healthy State. In the second Place, we must deduct a vast Quantity of Air from the Bulk of the Animal, since we find that the Lungs, Cavity of the Thorax, Stomach and Intestines, Abdomen, &c. are almost entirely fill'd with that Fluid. Thirdly, we must deduct the Blood and its Juices, which only distend

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extend the Vessels, Muscles, and Viscera to that Size in which they usually appear. Lastly, let the Nerves be deducted or separated from all the rest; and considered as Appendages of the Encephalon, and then upon comparing the nervous System with what remains, it will be found nearly, if not more than equal; for the Brain is destitute of all those Parts which serve to make up the Bulk of the Body, such as Fat, Muscles, Air, Blood, &c. and may be therefore consider'd as a mere Solid, excepting the subtil Juice it contains. In an Atrophy or Consumption, the small Blood-vessels are emptied of their Contents and collapse together, but the Nerves do notwithstanding appear as large and as sound as ever.

³ We have beautiful Experiments and Observations on this Subject communicated by *Malpighi*, assisted by the Microscope, though we have many of the same Observations in *Aristotle*, *Aquapendens*, and *Harvey*, who had not the Advantage of that Instrument; from them it appears that every single Egg which does not receive the Influence of the Cock consists of a Shell, Membranes, Chalaza, Albumen, and Yolk, with the Sacculus of Colliquamentum; and that upon opening another Egg, laid soon after the Hen had been trodden, the Sacculus or Colliquamentum appear'd by the Microscope to contain a Speck in its Middle, hardly bigger than the 1000th Part of a Grain of Sand, nor could any distinct Parts be observ'd therein; but upon opening another Egg that had been laid some Hours, he began to distinguish the Carina or incipient Chick in the Form of a Vermicle, or like a Tail arising from a large Head; and it is observable, that all Animals, whether Quadrupe, Fowl, Fish, or Insect, are, at their first Formation, of the same Shape, that is, like a Vermicle, consist-

ing

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ing only of Head and Tail; in the first of these, after a short Incubation, he distinguished two Vesicles or Hemispheres of the Brain, with the two protuberant Balls of the Eyes, while the Cerebellum appeared in Form of but one Vesicle, with the Medulla Spinalis extended from thence in the Form of a crooked Tail. After a few Hours Incubation all these appeared yet more distinct, and the Carina was beset with Protuberances, or Inequalities, which were the Rudiments of the incipient Vertebræ; at the same time appeared, by degrees, a kind of vibrating Arch extended from the middle of the Carina, which at length distinguished itself into four Sinus's, and being combin'd together form'd the two Auricles and Ventricles of the Heart; there was as yet no Appearance either of the Thorax and Lungs, or of the Abdomen and its Viscera, much less of the Extremities or Limbs, but all those Parts germinated by Degrees till the whole Chick was compleat. If these Observations be considered with due Attention, the nervous System will appear to be the Part which first exists in the incipient Animal; and from whence, in Conjunction with the arterial System, all the Viscera and other Parts are gradually form'd; hence it is that the Head bears so much greater Proportion to the rest of the Body, as the Animal is nearer to its Origin; and on the contrary, that the Viscera and Limbs are proportionably larger as the Animal is older. It is a Rule with Painters to give the Head of a new born Infant the Proportion of one to three in drawing its whole Body, but in Adults the Proportion is one to eight; whence it seems probable, that all the solid Parts of the Body are form'd by Degrees from the Brain and its Appendages, and that they consist chiefly of nervous Filaments.

All

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* All the Parts of an Animal have either Motion or Sensation ; and though the Heart, Lungs, and most of the other Viscera, have not a distinct Sensation, as being design'd to perpetual Motions, yet they are formed to be very sensible of Pain or a sort of Anguish whenever they are inflam'd ; but if they had been made very sensible they would have received Pain from their necessary and constant Motion ; the Bones indeed are said to have no Sensation, but Anatomists are very well acquainted that the compactest Horns arise from soft nervous Papillæ, and that the Nerves being form'd into a membranous Expansion give rise to all the Bones and Cartilages.

§. 302. It will also appear to be in no wise absurd for us to believe, that the smallest Vessels in the whole Body arising from the ultimate Arteriolæ become very much *like* the least Filaments of the Nerves, both as to Size, their contained Juices, and other Properties.

* The Aorta is a Compages of all the Series of Vessels ; for there are Branches arising from thence, which, being extended into Circles, are at length turned into Veins, lacteal Ducts, adipose Cells, &c. Even the whole Body will appear to consist of Arteries if we consider its Nutrition. I cannot, for my own Part, see any Reason why the smallest Series of Arteries, which are the pellucid Emissaries of the Carotids spent in the Cortex of the Brain, should not, some of them at least, be distributed for other Uses than Sense and Motion ; for Experiments convince us that those Actions depend entirely upon the Nerves which arise from the Brain.

Even

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Even if we meet with Vessels of the same Tenuity with the Nerves in any Part of the Body, their contained Juices must be of the same Subtilty with the Spirits or nervous Juice, §. 275 and 276. so that thus we shall have a sort of Nerves or Vessels of the minutest Size, not arising from the Brain, and whose contained Juices approach very near to the Nature of animal Spirits, being design'd for Nutrition, and therefore we call them natural Spirits.

§. 303. But that Part of the Blood which was sent to the Head, and not employ'd there for the Formation of Spirits, is carried off by the *lateral Arteries* ¹ to the Dura Mater, Cranium, Pericranium, Muscles, and other Parts about the Skull.

¹ Both the external and internal Parts of the Head; neither of them receive any Blood but what comes from the carotid and vertebral Arteries; the first of which having reached the Cranium, sends off each a lateral Branch externally, while the internal Carotid is inflected at its entering through the crooked Foramen observed by *Lower*, from whence it is distributed through the whole Substance of the Brain; but the other Branch or external Carotid, being distributed to the external Parts of the Head, sends off a Branch, which passing through a small round Foramen in the Cranium is spent upon the Dura Mater, the Impressions of whose Arteries are visible within the dried Skull; and it is from hence that the Palpitation and Heat of the Dura Mater arises.

§. 304. But the Dura Mater being also the internal *Periosteum* ¹ of the Skull, is a sort of Stratum or Basis in which those Arteries (§. 303.) are orderly disposed, and from whence they insert their small Twigs into the Bones themselves of the Cranium, upon which they are every way spent in very minute Branches ; but these small Arteries being distributed betwixt the thin bony Plates of the Cranium, intermixt with those from the Pericranium, and with them form very fine Plexus's, by which the Nutrition, *Warmth* ², and Secretion of the *Medulla* ³ in the Diploë, with the Growth of the bony Cranium *in Proportion* ⁴ to the Increase of its contained and other Parts, are all performed ; but having performed these Offices, the Blood speedily returns by the Veins.

¹ From that Branch of the external Carotid which is distributed upon the Dura Mater arise an infinite Number of small Arteries, inserting themselves from the convex Surface of the Dura Mater, through the internal Plate of the Cranium into its Diploë or Meditullium, upon whose Cells they are spent in reticular Plexus's. In the Skull of a Man that has been hang'd, these small Arteries (which serve as so many Ligaments to connect the Cranium and Dura Mater) being burst, occasion the Appearance of many red Points or Spots in the Dura Mater. Other Branches of the external Carotid are again distributed on the Surface of the Pericranium, from whence they penetrate through the external Plate to the Diploë, and mixing with
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the former Arteriolæ compose the Meditullium and discharge a medullary Oil.

² The Brain being naturally very cold from its Remoteness from the Heart, is in some measure warmed by the adjacent Arteries of the Dura Mater; which also communicate some small Motion to its cold Veins, which is one of the principal Offices of the Dura Mater towards the Brain. It is true, that *Baglivi*, and several other eminent Physicians, have imagined that the Action of the Dura Mater and its Arteries is so considerable as to compress the Brain, and propell its contained Juice alternately with every Systole of the Heart; but notwithstanding their Authorities, we know that the Cohesion of the Dura Mater to the Cranium is such as to cause its Arteries to make their Impressions on the Bones of the Cranium; whereas if the Dura Mater were loose, we should have the Figure of those Arteries impress'd upon the softer Substance of the Brain. To this it has been objected by a Person of Note, that there was a time in which the Cranium was equally soft with the Brain; to which we answer, that it is evident the Arteries do not make their Impressions at that time, since their Magnitude corresponds to the Arteries of an Adult, which vastly exceed those of the tender Fœtus.

³ There is not indeed much Medulla here separated, but yet there is enough to prevent the Bones of the Cranium from being too brittle; for the Bones themselves are almost a mere Earth, friable, and with little Cohesion, as appears from chemical Experiments, as in a calcin'd Bone, which being dipt in Oil recovers its Hardness and Cohesion; this Effect of the Medulla is much greater in the tubular Cavities of the more movable

movable Bones, as in the Thighs, Legs, and Arms.

4 The Arteries of the Dura Mater, by propelling their Blood and Juices with which they are distended by the Force of the Heart, do, in the same Proportion, gradually distend and enlarge the soft Bones of the Cranium, whose Sutures continue membranous so long as they are capable of Increase, that is, to about the Age of twelve or fourteen Years. But the reductory Veins coming through particular Foramina of the Cranium, very rarely open into the Sinus's of the Dura Mater, as *du Verney* observes, but are generally inserted into the Branches of the external jugular Veins. But besides the Use of the Dura Mater, as a Periosteum, it also sends out Productions through the Foramina of the Cranium and Vertebræ of the Spine, to invest and secure the Nerves; but these Productions reflected, invest also the Outside of the Cranium and Vertebræ; from the last of which the Continuation is carried on to the Ribs, Clavicles, Humeri, and all the Bones of the Limbs, so, in short, as to be continuous with the Periostia, and invest all the Bones; whence the Dura Mater may be reckon'd the Origin of all the Periostia, which, if they could be artfully separated from all the Bones, would exactly resemble the outward Shape of a Skeleton. All these Periostia we know are Membranes, spread with vascular Plexus's, or an infinite Number of sanguiferous and lymphatic Vessels, in a reticular Disposition, from whence the vital and nutritious Juices are conveyed into the Substance of the Bones, as *Dr. Havers* has shewn at large in his elegant Treatise on the Bones.

§. 305. 'Tis next observable, that the Blood which comes nearest in Likeness to the Consistence or Solidity, Subtilty, Motion and Fluidity of that lately sent to the Head, is impell'd through the *subclavian* ¹, axillary, and brachial Arteries, into those of the *Hands* ²; where passing through the least Vessels like the fomer, it occasions that great Agility, Strength, Warmth, and sensible Perspiration observable there; for which same Reasons its Circulation must also be very quick thro' those Parts.

¹ These Arteries are so denominated from the Clavicles, under the Defence of which Bones they pass securely to the Arms in Men who go erect; but in Brutes who have their Necks pendulous, they pass into the upper or anterior Limbs without this Defence. We however observe, that those Animals who use the fore Limbs for catching their Prey and other Food, have these Bones or Clavicles given to them by Nature, to sustain the Scapula and Articulation of the Humerus, to enable the latter for moving in larger Circles; such as in the Species of Monkeys, Bears, Squirrels, Dormice, &c. which have also a short Neck like the human Species, and take their Food too like them, either erect or sitting.

² We become almost as wise by our Hands as by our Eyes; since it is the Hand that makes those various Machines by which we are let into the Knowledge of Nature: They make Telescopes for us to look into the Heavens, Microscopes to inspect and discern insensible Objects, &c. And

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therefore to enable these Limbs for performing their numerous, nimble, and exquisite Operations, it was necessary they should be supplied with the more active, fluid, and swiftly-moving Parts of the Blood, as we find they are by the adjacent Heart, next after the Head ; whence the Heat and Sweating of the Palms.

§. 306. But the Blood sent to the Hands, as well as that brought to all other Parts, being separated and distributed by the smallest arterial Vessels, is by them carried into the *Bones*¹ and their Medulla, into the *Membranes*², *Muscles*³, *Fat*⁴, Glands, and Skin ; where vanishing through their exceeding Tenuity, they return again in reductory Vessels, gradually enlarging ; by which the arterial Blood and Juices are again returned through the Veins of the Hand to those of the Arm and Shoulder, and from thence by the Cava to the Heart.

¹ All the Bones are on every Side invested, except at the Insertions of their Ligaments and Capsules, with a Membrane call'd therefore Periosteum ; which is a reticular Plexus or Intertexture of an infinite Number of small sanguiferous Arteries and Veins, as well as Nerves and Lymphatics : But from the larger of these sanguiferous Arteries arise smaller ones, which penetrate to the interior Fabric of the Bones, and enter betwixt their Lamellæ, throughout every individual Part. But besides these Vessels of the Periosteum investing the Bones both without and withinside, the Bones have also in their Cavities other larger, medullary
Blood-

Blood-vessels, which generally penetrate them thro' large Foramina in their Epiphyses or Heads; which last Vessels are not spent on the bony Lamellæ like the former, but are distributed on the medullary Loculi of the very fine cellular Membrane contained within the Bones for the Reception of the medullary Oil; which is also in Part separated from the Arteriolæ of the internal Periosteum, which insinuates itself thro' the Foramina of the Epiphyses Ossium, with the larger Vessels, and lines the Bones internally as the other Periosteum does externally. As for the Blood brought into the Bones by those Arteries, it is returned by corresponding small Veins passing out through the oblique Foramina of the Bones, and opening into the adjacent Veins of the exterior Periosteum, and thence it passes to the larger Trunks. Thus the Blood seems to have a twofold Circulation through the Bones; one from the Arteriolæ of the internal Periosteum through the Pores, and betwixt the Lamellæ of the Bones; the other from the Arteries, spent reticularly on the medullary Cells without entering into the compact Substance of the Bone; thus, for Example, in the Cranium, you will have a clear View of this twofold Circulation, by supposing the Brain to be the oily Medulla of a Bone; so that the Pericranium and Dura Mater which detach Arteries into the Lamellæ of the Bones, will represent the Periosteum internum and externum; but the Pia Mater will denote that Part of the internal Periosteum which supplies Arteries distinct both in Course, Origin, and Distribution from the preceding.

² All which are by *Ruyfch* demonstrated to consist of Fibres and small Vessels variously interwoven and intersecting each other.

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3 The whole Compages of the Muscles are composed of Fibres from the Nerves, which we have demonstrated continuous with the Arteries (*per* §. 270 and 284.); upon which Fibres are again spread the Arteries, Veins, and Fat, transfusing into the cellular Membrane from the Arteries; the diaphanous Fibres being manifestly the Production of the Nerves (*per* §. 440.), whence it is manifest, that the whole Substance of the Muscle is continuous with the Arteries.

4 The Adeps, which is a fat Oil, passes mix'd with the Blood through the Arteries and Veins in all Parts of the Body, as is evident even to the Eye by the Microscope; but from the smallest of those Vessels, at their Anastomoses, it is deposited into the Cells of the adipose Membrane, out of the Course of the Circulation. Where the small Arteries and Veins unite by Anastomoses, there are lateral Communications with the blind Oil Cells for the Reception of the Fat, which being lighter than the other Parts of the Blood will both move on slower and more oblique or laterally, so as to enter the Cells, while the more dense Parts of the Blood proceed more in a right Line according to the Axis of the Arteriola, into the corresponding Vein. But no Juice has a greater Tenacity than Oil, and therefore it will not perspire or be consumed, but accumulated. Hence we may easily perceive how a Person may become of a monstrous Bulk by mere Obesity; and how a Person may become thin again by the mere Motion of the Muscles only accelerating the Blood through its Vessels, and at the same time expressing the Oil into them from its containing Cells? We can also from hence give a Reason why lean People have much and fat People but little Blood in their Vessels. I have observed, after *Lewenhoec*, a small Portion of a Muscle

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Muscle from a lean Ox looked red and full of Blood, but a like Portion of the Muscle from a very fat Sheep manifested no Appearance at all of Blood, but seemed a continued Mass of Fat: Another time I dry'd a Muscle from a very lean Plow-horse, and viewing a Bit of it with a Microscope, it appeared uniformly red and nothing else; but a Piece of the Muscle from a fat Ox being prepared and examined in the same manner, shewed very little Redness by the Microscope, but seem'd rather a mere Particle of Fat.

§. 307. For it must be observed, that the Extremity of every small Artery is accompanied, in all Parts of the Body as well as in the Limbs, with a sort of glandular Apparatus (approaching the Fabric of §. 250.) from whence a Vessel arises, carrying off the different Humour here separated, whether it be ferous, *lymphatic*¹, aqueous, or oily; by which Vessel the said Humour also returns again into the Vessels, and mixing with the rest of the Blood in the *Veins*², returns by them to the Heart: Such an Apparatus is proved from Dropsies of all kinds, and especially the *Anasarca*³; from a lymphatic Tumour or Swelling of those Parts which have had their *Veins*⁴ obstructed by Ligature; from *fistulous*⁵ Ulcers, *Hydatids*⁶, *Phlyctenæ*⁷, the *Itch*⁸, Eruptions, or *Granula Hordacea*⁹, frequently observed in the Fat of Pork and other Animals; from whence it also appears, that this secretory Apparatus is to be found alike in all Parts¹⁰ of the Body.

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¹ We evidently perceive that there is secreted every where a limpid Liquor like Lymph; but we are not assured that the Secretion is made by glandular Machines, since we only meet with their Appearance in Diseases.

² Thus the Juices of several Kinds is returned into the Blood, to be again separated from thence for the same Purposes.

³ An Anasarca is a Collection or Stagnation of an aqueous Humour, either in the Lymphatics or in the Cells of the Membrana Adiposa, in whose Cells the Arteries ought only to deposit Fat in a healthy State; but since there is no Part of the whole Body but what is liable to this Species of Dropsy, it follows, that there must be a sort of glandular Apparatus in every Part, from whence the said lymphatic Humours arise,

⁴ We know, by Experiment, that a Ligature made on the sanguiferous Veins of a Part occasions the Lymphatics to swell and become visible by the Accumulation of their Juices, which before had a Passage into and through the sanguiferous Veins. This Experiment may be beautifully made by fixing a Ligature on the Vena Cava of a living Dog, as it was first performed by *Lower*, who, however ought not to have thence concluded, that therefore every Dropsy was seated in the Lymphatics, which only makes that Species described by *Hippocrates*.

⁵ Fistulous Ulcers discharge a great deal of a Liquor which is neither like Blood nor Matter; especially when those Ulcers penetrate to the Periostia of the Bones. When a Surgeon makes a Fontanel by applying a Cautery to the Cranium, at first indeed the Blood follows, but in a Day or two afterwards it pours out a mere Lymph; whence
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it follows, that there must be lymphatic Vessels there.

⁶ Hydatids are round pellucid Tumours, formed by an aqueous Humour retained in a thin Membrane : Nor can they well be said to be no more than Varices of the Lymphatics ; for they being obstructed dilate into a Sphere, whence it would seem that their Cells were at first spherical, but invisible before they were preternaturally distended by Disease. These Hydatids are often formed in the Uretus, and *Ruysch* has found the whole Liver turn'd into these Vesicles.

⁷ Phlyctenæ are oblong, pellucid, and lymphatic Vesicles ; being the true Varices or Aneurisms of the Lymphatics. They frequently happen in the Eyes and endanger their Sight ; as happen'd to a young Student who came under me, being very solicitous to preserve his Sight : In this Patient I could observe, with a Microscope, that the Artery which is extended over the Pupil was much enlarged and distended into Protuberances or Aneurisms of this kind ; therefore the Vessel being removed and opened by a Needle with a suspended or gentle Hand, the Water ran out and his Sight returned.

⁸ Chiefly the Itch, which is formed of small Pustules, including a sharp Ichor under the Cuticle, and which excites an intolerable itching. For the small Vessels of the Cutis which lay before concealed under the Cuticle, become so distended in this Disorder as to be visible and irritated, either by some acrid Virus, or even Animalculæ, according to *Redi* and others. When the reticular Body of *Malpighi* has been eroded and consumed in the Itch it proves of the very worst Kind, and if that Erosion extends to the Skin itself it produces a Le-

prosy; but if it extends even through the Skin to the subjacent Membrana Adiposa, it produces the direful Malady termed *Lepra Arabum*, frequent among the Inhabitants of *India, Arabia, Egypt, and Palestine.*

⁹ Swine are often liable to the Measles, which are round little Grains like Barley, full of a serous or thicker Juice, which ought in a healthy State to be only Fat or Oil: For that they are really Follicles of the cellular Membrane appears from the *Ruyfchian* Art of Injection, by which the small cutaneous Arteries are fill'd so as to force the Liquor even into the Cells of the fat Membrane. And possibly the serous Arteries may also communicate in like manner with the Cells, if we could subject them to the same Experiment.

¹⁰ In some Parts the Juices brought by the Arteriolæ fly off insensibly in Form of Vapours, which are partly retained in Cavities of the Body, and partly exhaled into the Air.

§. 308. Next, that Part of the Blood which has a finer or looser Texture, being thicker and less fluxile, is by the Laws of Hydraulics forced into the *descending*¹ Trunk of the Aorta, where the more simple Parts of the same Blood will enter the *intercostal*² Arteries, and after having performed its Office with great Celerity in the Muscles of Respiration, it passes the quickest of any (but §. 305.) into the corresponding Vena Azygos, and from thence by the Cava to the Heart. By the admirable Contrivance and Disposition of these Vessels the *Circulation*³ is render'd exceeding
free

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free through them, without any Resistance or Hindrance from the large Quantity already in the Vena Cava; since the Parts which discharge their Blood into that Vein, *viz.* the Interstices of the Ribs, and most of the Membranes in the Thorax, will not bear any Obstruction without the most imminent and present Danger of Life. For this Reason therefore the Vena Azygos *discharges* + itself in that Part of the Cava where it is the soonest emptied into the right Auricle and Ventricle of the Heart in its Diastole; and for the same Cause the Passage from the Arteries into the Veins is here free and open: From whence one may understand the Reason of the quick Circulation through these Parts, and why so many of the most *acute* ⁵ Diseases frequently infect them.

¹ From thence arise first the coronary Arteries of the Heart, then those of the Pericardium, and next the Arteries of the Mediastinum. But it must be remarked, that in the human Body there is but one arterial Trunk, though in Brutes who go with their Necks pendulous there are two Trunks, one ascending and the other descending, as *Ruyfch* has very justly asserted and shew'd in Opposition to *Bidlow*.

² The Intercostals arise from the Aorta at right Angles, and from thence pass in the Channels of the Ribs, cover'd before by the Periosteum; but they do not run through the Pleura, only in the cellular Membrane betwixt the Pleura and Periosteum of the Ribs. *Ruyfch* has demonstrated that
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these Arteries are spent in the intercostal Muscles, Pleura, Cartilages of the Ribs, and even the Skin itself on those Parts, as *Eustachius* had long before observed, who, one should think, could hardly have observed and traced so diligently the Branches of the Vena Azygos if he had not been acquainted with some Method of injecting them, which yet does no way appear.

³ It is altogether singular, and somewhat surprising that the Blood returned from all the external and internal Parts of the Organs of Respiration, both Viscera, Membranes, and Muscles, does not go to the Heart by the common Channel of the Vena Cava but by a peculiar Vein for that Office, termed *Vena sine pari*. For the small Veins of the Pericardium, Mediastinum, the subcutaneous Veins from the Outside of the Thorax, those of the Pleura, the Intercostals, those of the Diaphragm, and Parts adjacent, and possibly some from the Liver which are less easily discovered; all open into the Vena Azygos, as the excellent *Eustachius* first observed, who seems to have prosecuted Anatomy with Application and Exactness more than human. The Vein we now speak of is large, and placed on the Right side of the Bodies of the Vertebrae and Vena Cava, a little above the Pericardium, and inserts itself into the adjacent right Auricle. The Reason for which peculiar Vein to the Organs of Respiration seems to be this. Every Person is obliged to draw in and expel the Air again from their Lungs alternately, so long as they live; to perform which Action requires also an alternate Contraction and Relaxation of the intercostal Muscles; whence it was absolutely necessary there should be a free Passage for the Blood from the intercostal Arteries through the Muscles
into

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into the Veins, and that easily and without any Delay: But the Motion of Respiration greatly accelerates upon any Exercise of the Body (*per* §. 208.), since the Blood then returns quicker by the Veins to the Heart, which must therefore protrude it more swiftly through the Lungs; which accelerated Motion of the Lungs supposes an increased Action of the Parts employ'd in Expiration and Inspiration; whence if the Blood of the intercostal Veins had passed immediately into the Cava, there would have been Danger of those smaller Vessels being over-charged, and distended or obstructed, whenever the Blood was more than ordinarily accumulated in the Cava; whence the Parts which are in themselves very sensible and prone to Inflammation, would have been much more subject thereto than they now are. Nature has therefore thus providently guarded against a fatal Pleurisy, by furnishing these Parts with a peculiar Vein, communicating with the upper and lower Cava, and receiving the Blood from the Organs of Respiration, to deposit the same in the Cava when it resists the least, that is, when the Heart relaxes and takes the Blood of the Vena Cava and Azygos into its right Auricle and Ventricle. Hence therefore it appears, that the Ancients did not without Reason place the Seat of a Pleurisy in this Vein, which they studiously endeavoured to empty in that Disorder; for though the Seat of Inflammation is not in Veins, yet in this Part it is not far from them, *viz.* in the Resistance given by these distended Veins to the intercostal Arteries. Add to this, that the Veins before described are all deeply situated out of the Influence of any Irregularities from the unconstant Actions of the voluntary Muscles.

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⁴ Both the Insertions of this Vein are furnished each with a Valve at their Entrance in the Cava.

⁵ There are scarce ten People who perish by acute Diseases, but nine of them die pleuritic; not only from the Shortness of the Vessels and Vicinity to the Heart, but also from their greater Repletion, by removing the Pressure of the Air from them in Inspiration, by the Stimulus of these Muscles continually in Action, from the Nearness of the cold Air inspired, and from the Swiftiness of the Blood's Circulation here, &c. which dispose a fizy or inflammatory Blood more to shew its Effects in these Arteries than in others.

§. 309. After these the *phrenic* Arteries, with the Pericardio-diaphragmatics, receive the like Blood with the intercostal and vertebral Arteries, through which the Blood circulating very swiftly into the phrenic Veins, passes from them into the Cava; whence these Vessels also conspire to render the Return and Circulation of the Blood, free, swift, and constant.

The Ancients gave the Name *φρενες* to that Part which we now call the Diaphragm; because they imagin'd that the Mind resided there in a particular manner: But the Diaphragm has some Arteries from those of the Mediastinum, and others from those of the Pericardium, as *Ruyssch* has demonstrated; all which various Arteries communicate together, as the Pericardium is closely attached to a great Part of the Diaphragm; from which communication the Circulation is again rendered

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rendered more free ; which was the more necessary as the Part is so liable to Inflammation, the Pleuritis and Peripneumonia being hardly ever observed without some degree of the Paraphrenitis, which seldom arises of itself but from one of the former. From the Connection of the Diaphragm one may understand why such an intolerable Heat is perceived there when it is disorder'd ; and why, when the Diaphragm is inflamed, the Pericardium and Parts adjacent generally partake of the Disorder by the Communication of their Arteries. The Blood of these Parts seldom returns by the Vena Azygos of *Eustachius*, which he indeed observed, but I never yet saw it ; and though *Eustachius* refers the phrenic Veins to the Azygos, they are generally referred to the Cava by Anatomists.

§. 310. The descending Aorta passing next through the Diaphragm, sends its Blood (agreeable to §. 306 and 307.) to the Loins, Abdomen, Thighs, Legs and Feet, from whence the Blood returns again by the Veins, furnished with *Valves* : in the lower Parts of the Body.

• The Blood of the lower Limbs meets with a very difficult Return to the Heart, as moving slower than the rest, and against its own Weight : If indeed the Aorta and Cava communicated as openly as the two Legs of a Syphon, the perpendicular Weight of the Blood descending in the first would counterpoise that ascending in the last ; but the infinite Ramification of those Vessels betwixt their Trunks, break off the Force of the Heart, Aorta, and Arteries, and the Blood re-
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turns but very slowly upwards in the Veins ; in weak Vessels it is retarded by its own Weight, and often distends the yielding and weak Coats of the Vessels into Varices : But to alleviate these Inconveniences, in some measure, Nature has supplied those Veins of the lower Extremities, which most require them, with Valves, which sustain the Weight of the superior Blood from pressing on the inferior ; so that by dividing a large venal Tube as it were into so many smaller ones by Valves, the Blood will both be prope'll'd by the Re-action of the elastic Valves, pressed by its Weight, and the contractile Force of the adjacent Arteries and Muscles will have a greater Power to send it forwards in small Parcels than if it was in a continued perpendicular Cylindar.

§. 311. Now from the same descending Trunk of the Aorta below the Diaphragm, arise *Arteries* ¹ which are ramified to all the *Viscera* ² of the Abdomen, in which they are formed or disposed nearly into a glandular Fabric, and may be commodiously distinguished into those Branches which serve to the Formation of Chyle, termed *Chylopoætic* ³ ; those for the Secretion of Urine, termed *Ouropoætic* ⁴ ; and those for the Separation of Semen, termed *Spermatopætic* ⁵.

¹ These are reducible to three capital Trunks, of which the first is (1.) the *Celiac* Artery, arising from the Aorta immediately below the Diaphragm ; (2.) the *Mesentrica superior* ; and (3.) the *Mesentrica inferior* : From which three Arteries

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ries all the abdominal Viscera are supplied with Blood.

² By a Viscus we understand an organic Part of the human Body, which receiving the arterial Blood, does, by the Power of its Fabric, work some Change therein, and then returns the said Blood again to the Heart by the Veins. These Viscera of the Abdomen are contained within the Peritonæum, that is, wrapped up in the Dupli-catures thereof, and not contained in it as in a Bag: For the Peritonæum being extended from the Loins over all the Viscera, forms as it were a distinct Bag to receive each, so that there are in reality as many Duplicatures or Sacculi of the Peritonæum as there are Viscera, except the urinary Parts, which are without the Peritonæum, and covered by it only on their Fore-side.

³ The *Chylopoetic* are those of the Liver and Spleen, Omentum, Stomach, Pancreas, Mesenteric, Intestines, with the mesenteric Glands, and the three Kinds of Vessels before enumerated.

⁴ The *Spermatic* are those of the Testicles and seminal Vesicles in Males; and in Women those of the Uretus, the Ovaria, and their mothwing'd Expansions, with the Plexus's extended to the Thighs, and their Vessels.

⁵ The *Ouropoetic* are those of the Kidneys and their Glandulæ or Capsulæ Atrabiliaræ, with the Emulgents. But of all these Arteries we must begin first with those that come first from the Aorta, and are distributed into the chyloificative Viscera, viz. the cœliac Artery and its Branches, among which we are again to begin first with the Branches going to the Spleen, because the
Blood

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Blood must be first prepared in that Body before it goes to the Liver, and therefore the Action of the Liver cannot be well understood before we have survey'd that of the Spleen, which is an Organ that does not work for itself but for the Good of others, serving for a Purse or Sieve, to which the Emperor *Trajan* formerly compared it with a great deal of Justice.

F I N I S.







